AD-A058 147 NAVAL ENVIRONMENTAL PREDICTION RESEARCH FACILITY MON--ETC F/G 4/2
TYPHOON HAVENS HANDBOOK FOR THE WESTERN PACIFIC AND INDIAN OCEA--ETC(U)
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WESTERN
INDIAN OC

by

BRAND and JACK W.

COMMANDER IN CHIEF
UNITED STATES PACIFIC FLEET
(MAKALAPA, HAWAII)
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IN REPLY REFER TO:
FF1-1
3145
Ser 02M/ 710
26 Jan 1978

From: Commander in Chief U. S. Pacific Fleet
To: Distribution

Subj: Typhoon Havens Handbook

Ref: (a) CINCPACFLT ltr 3145 Ser 02M/4729 of 11 June 1976

Encl: (1) Typhoon Havens Handbook for the Western Pacific and Indian Oceans, NAVENVPREDRSCHFAC Technical Paper No. 5-76

1. Enclosure (1) was developed by the Naval Environmental Prediction Research Facility (NAVENVPREDRSCHFAC) in response to a validated COMSEVENTHFLT requirement to evaluate selected Western Pacific and Indian Ocean ports as typhoon havens. Initial distribution was promulgated by reference (a) and included typhoon haven studies for the following ports: Apra Harbor, Kaohsiung, Chilung (Keelung), Hong Kong, Yokosuka, Numazu, Iwakuni, Kure, Sasebo, Kagoshima, Buckner Bay, Naha, Subic Bay and Manila.

2. Change ONE to this handbook contains additional haven studies. These are for the following ports: Cebu, Philippines; Inchon, Pusan and Chinhae, Korea; Colombo, Sri Lanka; Karachi, Pakistan; Auckland, New Zealand; Fremantle (including Cockburn Sound), Australia; and Diego Garcia. More haven studies will be forwarded later as they are completed.

3. Enclosure (1) is forwarded for retention to aid commanders and commanding officers of ships in evaluating a typhoon situation and to assist them in making decisions in whether to sortie to evade or remain in port and take shelter within a specific harbor. Comments concerning the usefulness of the enclosed publication are encouraged.

JOHN C. DIXON, JR.
Deputy Chief of Staff
for Operations and Plans

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Monterey, CA 93940

RECORD OF CHANGES

Change #	Authority	Date Entered	Entered By/Comments
1		August 14, 1978	Patricia [illegible]
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REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER ~~NAVENVPREDRSCHFAC~~ NEPRF-Technical Paper [redacted]-5-76-rev	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle) 6 Typhoon Havens Handbook for the Western Pacific and Indian Oceans. Revision	5. TYPE OF REPORT & PERIOD COVERED
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) 10 Samson Brand ~~and~~ Jack W. Blelloch	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Environmental Prediction Research Facility Monterey, CA 93940	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS Air Task - A370-3706/076C/6W0S33-000 NEPRF WU: 055:3-2
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Air Systems Command Department of the Navy Washington, D.C. 20361 11 7 Feb 78	12. REPORT DATE June 1976/February 1978
	13. NUMBER OF PAGES 374
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) 16 WØS33 12 391p.	15. SECURITY CLASS. (of this report) UNCLASSIFIED
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

17 WØS33ØØØ

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

Revised edition of AD-A034 188

18. SUPPLEMENTARY NOTES

(1) Sections I-VI (less port of Cebu in Sec. VI) dated June 1976. (2) Sections VII-XII (plus port of Cebu in Sec. VI) dated February 1978. (3) Sections I-VI AD No. AD-A034 188.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Typhoon
Tropical Cyclone
Typhoon Haven
Tropical Meteorology

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This document is a compilation of many typhoon haven studies of ports and harbors of the western Pacific and Indian Oceans previously published by the Naval Environmental Prediction Research Facility. The original studies, which were written for the operational meteorologist, have been heavily edited, restructured and condensed for presentation in this form.

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20. Abstract (continued)

This document is intended as an aid in decision making for commanders, ship captains and ship routing personnel regarding typhoons which threaten the ports discussed.

FOREWORD

The impetus for this Handbook was a request from Commander SEVENTH Fleet that certain Pacific and Indian Ocean ports be evaluated as typhoon havens. Evaluations of the ports presented here have been initially published as individual NAVENVPREDRSCHFAC Technical Papers which included considerable information of interest primarily to meteorologists. Those evaluations have been extensively rewritten and condensed for presentation in this Handbook.

This Handbook is oriented toward the commanding officer or other individuals responsible for making decisions regarding storm evasion that pertain to these specific ports. The purpose is to provide a single-volume reference to aid in decision making.

Many of the original studies were completed as theses by students in the meteorology curriculum of the Naval Postgraduate School under the direction of Dr. George J. Haltiner. Numerous Naval Weather Service Environmental Detachments, Fleet Weather Facilities and Fleet Weather Centrals provided data, reports and constructive comments as did foreign representatives at the ports studied. All the above contributions are gratefully acknowledged as is the assistance and encouragement of CDR J. J. Maloney and CDR N. F. O'Connor during their tours as Staff Meteorologist, COMSEVENTHFLT and CDR G. B. Delano, Assistant Fleet Meteorologist and Oceanographer, CINCPACFLT.

The development of this Handbook is a long-term and continuing project; evaluations of other ports will be published for future inclusion in the Handbook. Every effort has been made to make this Handbook as concise as possible and yet sufficiently comprehensive to cover most contingencies to be encountered under threatened or actual typhoon conditions in the ports presented.

However, until the Handbook has been used by the operating forces in real situations, its true value cannot be measured. The Handbook is conceived as a flexible document to be modified and updated as required to reflect the needs and recommendations of the operating forces. Accordingly, comments and criticisms by Fleet users as to the utility and value of the Handbook are urgently solicited.

R. C. Sherar

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INTRODUCTION

Severe tropical cyclones, also known as typhoons or hurricanes, are among the most destructive weather phenomena a ship may encounter whether the ship be in port or at sea. When faced with an approaching tropical cyclone, a timely decision regarding the necessity and method of evasion must be reached. Basically, the question is: Should the ship remain in port, evade at sea, or if at sea, should it seek the shelter offered by the harbor? This study examines a number of western Pacific and Indian Ocean ports and evaluates their potential as typhoon havens. This information should provide useful guidance to commanding officers in answering the above questions.

In general it is an oversimplification to label a harbor as merely good or bad. Consequently, an attempt is made to present enough information about the harbors to aid a commanding officer in reaching a sound decision with respect to his ship. The decision should not be based on the expected weather conditions alone, but also on the ship itself, as well as characteristics of the harbor. These characteristics include: natural shelter provided, port congestion, and support facilities (normal and emergency) available.

Chapter I presents a general description of tropical cyclones and the environmental phenomena associated with them. Discussions of ship performance under tropical cyclone conditions, and details of tropical cyclone warnings are also given.

Each remaining chapter presents information about a particular geographical area including details of individual ports and harbors, local topographical influences on tropical cyclones, and helpful guidelines for the decision-making process of whether to sortie or remain in port.

On the basis of the studies conducted in the development of this handbook, each port considered has been given an adjective rating of its suitability as a typhoon haven. These ratings are presented as Table 1.

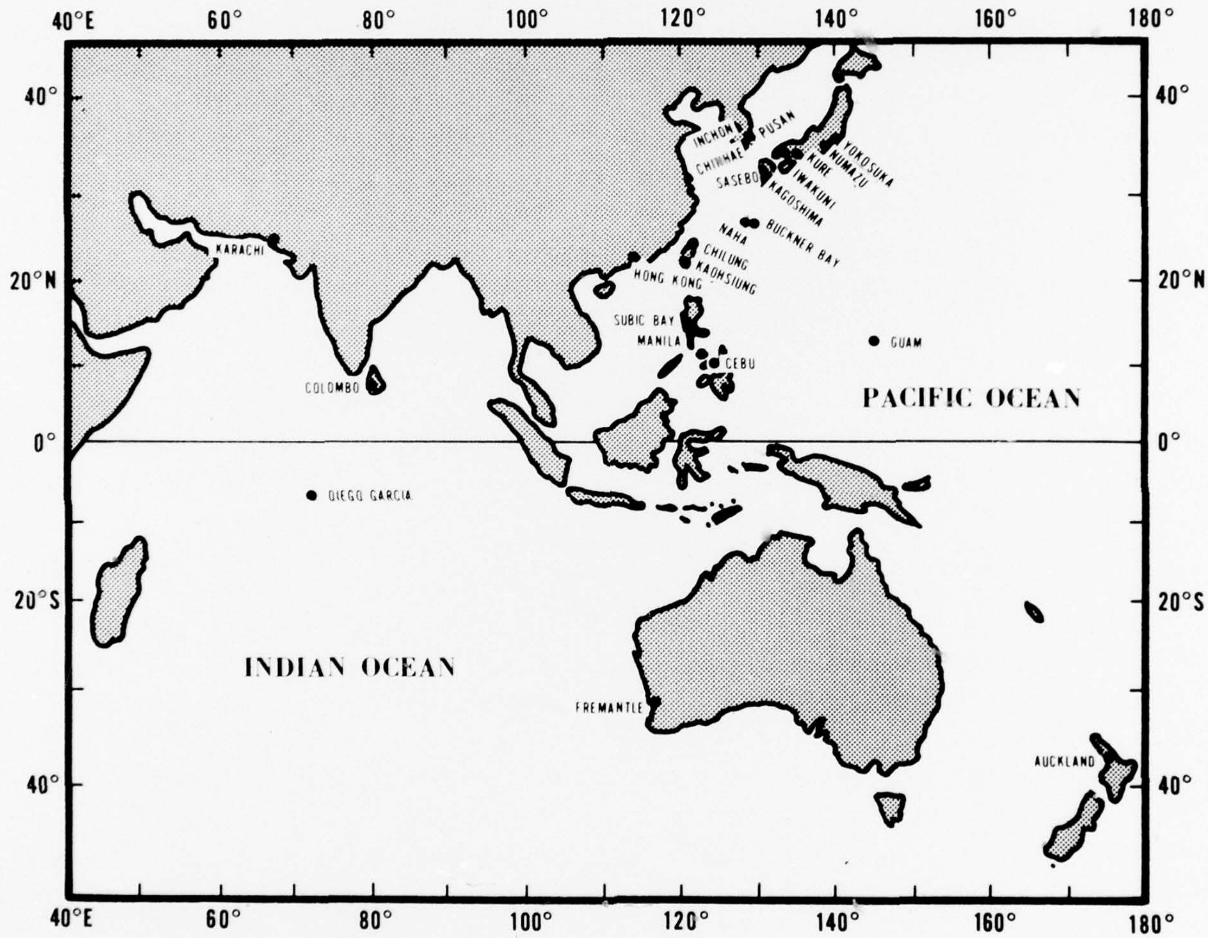

Figure 1. Locator map of western Pacific and Indian Ocean ports evaluated as typhoon havens.

Table 1. Ratings of western Pacific and Indian Ocean ports evaluated as typhoon havens.

GUAM	
APRA HARBOR	POOR
TAIWAN	
KAOHSIUNG	POOR
CHILUNG (KEELUNG)	POOR
HONG KONG	
HONG KONG HARBOR	POOR
JAPAN	
YOKOSUKA	GOOD
NUMAZU OPERATING AREA	POOR
IWAKUNI	MARGINAL (but has easily accessible anchorages close by which are considered good)
KURE	GOOD
SASEBO	GOOD (except for carriers)
KAGOSHIMA	POOR
BUCKNER BAY, OKINAWA	POOR
NAHA, OKINAWA	POOR
PHILIPPINE ISLANDS	
SUBIC BAY	MARGINAL TO POOR
MANILA	POOR
CEBU	POOR
KOREA	
INCHON	POOR (unless shelter is available in the tidal basin; then it would be considered a good haven)
PUSAN	POOR
CHINHAE	MARGINAL (but has easily accessible anchorages close by which are considered good)
SRI LANKA	
COLOMBO	GOOD
PAKISTAN	
KARACHI	MARGINAL
NEW ZEALAND	
AUCKLAND	GOOD TO MARGINAL
AUSTRALIA	
FREMANTLE	MARGINAL (unless shelter is available in Cockburn Sound or the inner harbor; then it would be considered good)
DIEGO GARCIA	
DIEGO GARCIA HARBOR	POOR

I TROPICAL CYCLONES— A GENERAL DISCUSSION

1. TROPICAL CYCLONE DEVELOPMENT

Tropical cyclones are warm-core, nonfrontal low-pressure centers that develop over tropical or subtropical waters. Although the tropical cyclone formation process is not fully understood, it is well known that they require tremendous amounts of energy to develop and sustain the high wind velocities present. Only the warm moisture-laden air of the tropics possesses this quantity of energy. For this reason, tropical cyclones usually develop within 20° of the equator and begin to dissipate as they move into midlatitudes.

2. WIND CIRCULATION AND INTENSITY

The wind circulation associated with tropical cyclones is counterclockwise about the eye in the Northern Hemisphere and clockwise in the Southern Hemisphere. Figure I-1 depicts the wind pattern around the eye of a typical large, intense 150-kt typhoon. Note that the more intense winds are located in the right semicircle of the circulation. For this reason the right side of a tropical cyclone is known as the "dangerous semicircle."

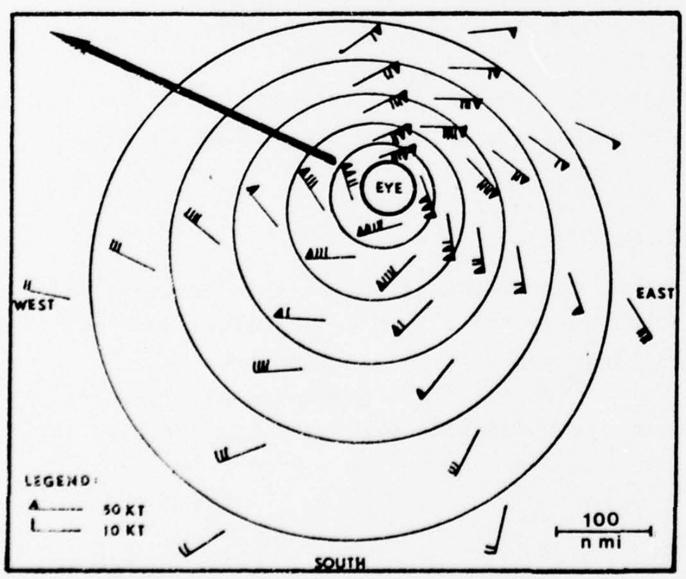

Figure I-1. Distribution of surface wind speeds (in knots) around a large, intense typhoon in the Northern Hemisphere over open water. The arrow indicates direction of movement (after Harding and Kotsch, 1965).

SECTION I - CONTENTS

The highest winds associated with tropical cyclones have never been accurately measured; however, based on data from past storms, tropical cyclone winds may attain speeds well in excess of 150 kt. The following classification system concerning the intensity of tropical cyclones has been established by international agreement:

Tropical Depression:	Maximum sustained winds no greater than 33 kt
Tropical Storm:	Maximum sustained winds in the range 34-63 kt
Typhoon:	Maximum sustained winds in excess of 63 kt

3. TROPICAL CYCLONE MOVEMENT

The subject of tropical cyclone movement is very complicated since precise speed and direction of movement is a function of wind and pressure patterns from the sea surface to the top of the atmosphere. In general, tropical cyclones in WESTPAC begin in the tropics and move west or west-northwest. In some cases the movement eventually becomes northward and finally northeastward. This shifting of direction is known as recurvature. Appendix I-A presents the mean tracks of tropical storms and typhoons in the western North Pacific by month and part-monthly periods (NAVAIR 50-1C-61, 1974).

Prior to recurvature, tropical cyclones generally move at speeds from 8 to 14 kt; however, after recurvature they may accelerate and within 48 hours reach speeds 2-3 times greater than that at the point of recurvature. (This acceleration varies with the time of year.) During the recurvature process the tropical cyclone is moving farther from the tropics; in doing so, it comes into contact with cooler surface waters and air from extra-tropical regions is drawn into its circulation. These factors result in the ultimate dissipation of the tropical cyclone. Approximately 40% of western North Pacific tropical cyclones recurve (Burroughs and Brand, 1972).

Appendixes I-B through I-D present the mean tracks of tropical cyclones for the North Indian Ocean, Southwest Indian Ocean and the Southwest Pacific Ocean/ Australian areas respectively.

4. SEA STATES AROUND TROPICAL CYCLONES

It is important to realize that sea conditions affecting ship movement will extend well beyond the wind field associated with a tropical cyclone, and that a miscalculation concerning sea conditions could result in a destructive rendezvous with the storm. The extent of the sea state generated by a tropical storm is primarily a function of storm size, duration and intensity. Figure I-2

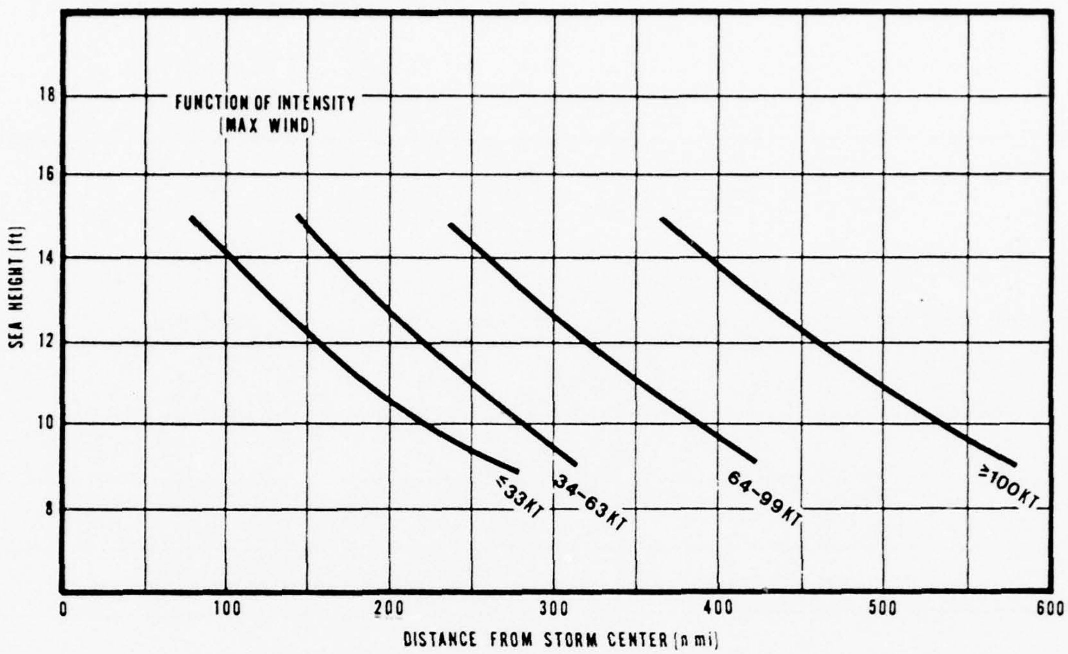

Figure I-2. The sea height (9 to 15 ft range) around 21 tropical storms and typhoons (based on 173 analyses for the year 1971) plotted against distance from storm center and given as a function of intensity.

shows the sea height associated with 21 tropical storms and typhoons to the east of the Philippines (based on 173 analyses for the year 1971) plotted as a function of distance from the storm center and storm intensity (Brand, et al., 1973). There is a large variation in the sea state with storm intensity. A tropical storm (winds 34-63 kt) could produce 12-ft seas 217 n mi from the storm center; while an intense typhoon (winds ≥ 100 kt) could produce 12-ft seas 454 n mi from the center. The distances given are mean distances since the isopleths of sea height are not symmetric about the storm center.

Brand, et al. (1973) found that the actual wave heights are at least partially dependent on the direction in which the storm is moving. For example, Figure I-3 shows the average sea-height isopleth pattern for storms moving to the west, northwest, and northeast and is based on sea-state analyses for tropical storms and typhoons that occurred during 1971. Note that the greatest area of higher seas (9-15 ft range) tends to exist to the rear and toward the right semicircle of the storm.

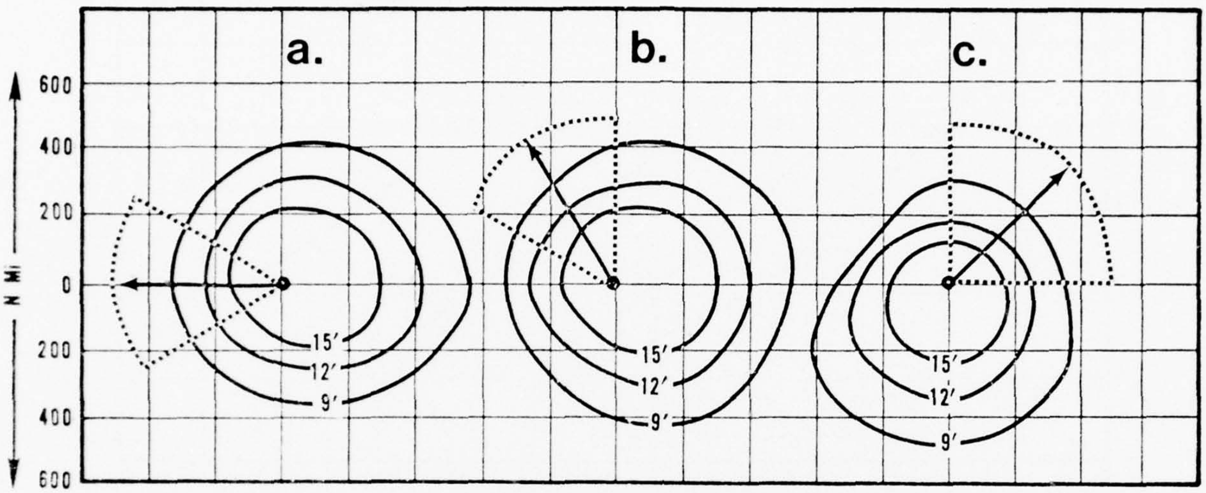

Figure I-3. The sea height isopleths (9-15 ft) about tropical storms and typhoons given as a function of direction of movement (a = 240°-300°; b = 301°-360°; c = 001°-090°).

5. SHIP SPEED OF ADVANCE VERSUS SEA STATE AND WIND

Figure I-4 represents the estimated resultant speed-of-advance of a ship in a given sea condition. The original relationships were based on data of speed versus sea state obtained from studies of many ships by James (1957). They should not be regarded as truly representative of any particular ship (Nagle, 1972).

For example, from Figure I-4, for a ship making 15 kt encountering waves of 16 ft approaching from 030° (relative to the ship's heading) one can expect the speed-of-advance to be slowed to about 9 kt. Twenty-foot seas, under the same condition, would result in a speed-of-advance of slightly less than 6 kt. However, it is emphasized that these figures are averages and the true values will vary from ship to ship.

Figure I-5 shows the engine speed required to offset selected wind velocities for various ship types (computed for normal loading conditions).

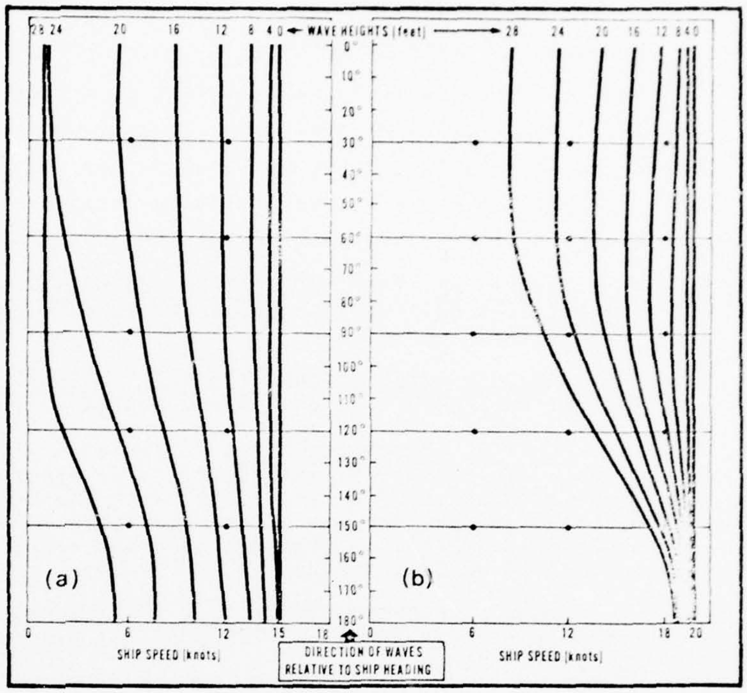

Figure I-4. Expected ship speed as a function of wave height and wave direction relative to ship's heading for (a) a ship speed of 15 kt and (b) a ship speed of 20 kt.

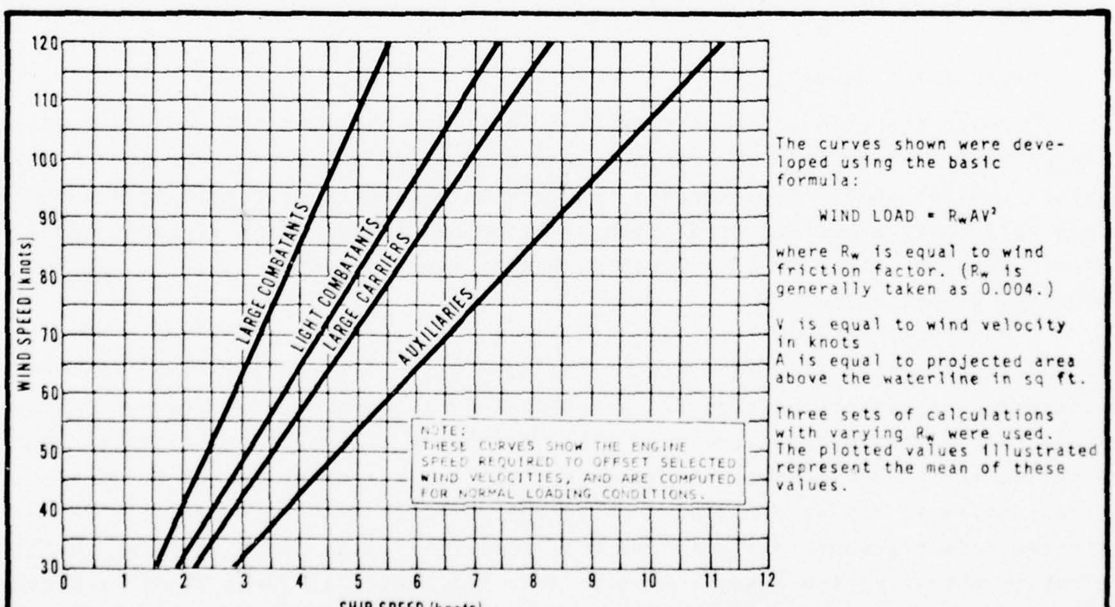

Figure I-5. Engine speed vs wind velocity for offsetting force of wind (from Crenshaw, 1965).

6. WARNING AND ADVISORY SERVICES

Fleet Weather Central/Joint Typhoon Warning Center, Guam (FWC/JTWC) offers a variety of warning and advisory services to WESTPAC and Indian Ocean units in accordance with COMNAVWEASERVINST 3140.1 (series). In the Northern Hemisphere west of the 180th meridian, the following tropical cyclone related bulletins are transmitted on Fleet broadcasts (see CINCPAC INST 3140.1 (series) for details):

SIGNIFICANT TROPICAL WEATHER ADVISORY - A narrative message which summarizes significant tropical atmospheric conditions (issued at 0600Z daily).

TROPICAL CYCLONE FORMATION ALERT MESSAGE - Issued when meteorological data indicates that formation of a tropical cyclone is likely.

TROPICAL CYCLONE WARNINGS - Issued on all tropical cyclones four times a day in the Western Pacific. Warnings are issued within 2 hours of 000Z, 0600Z, 1200Z, and 1800Z, with the constraint that two consecutive warnings may not be more than 7 hours apart. In the Bay of Bengal and Arabian Sea, the warnings are issued twice a day within 2 hours of 0800Z and 2000Z.

PROGNOSTIC REASONING MESSAGE - Issued for the WESTPAC area only, this message (at 0000Z and 1200Z daily) provides technical reasoning for latest forecast.

In the Southern Hemisphere, only Tropical Cyclone Formation Alerts and Tropical Cyclone Warnings are issued. The warnings are transmitted at 0000Z and 1200Z daily.

7. CALCULATING DANGER ZONES

Through aircraft reconnaissance and satellite observations, modern techniques for locating tropical cyclones and monitoring their progress have become quite sophisticated. Nevertheless, the present state of meteorological knowledge does not permit a perfect prediction of storm movements. Many variables exist which can alter the path of a typhoon; hence, every typhoon should be treated with the utmost respect.

COMSEVENTHFLT OPORD 201-(YR), Annex H (also CINCPACFLT OPORD 201-(YR), Annex H), describes the techniques to be used when plotting the Fleet Weather Central/Joint Typhoon Warning Center (FWC/JTWC) typhoon warning track positions. An average 24-hr forecast error of 135 n mi should always be incorporated when plotting the 24-hr forecast position in order to expand the radius of 30-kt winds, given in the warning, by the average forecast error. Figure I-6 demonstrates this procedure and utilizes the 135 n mi average 24-hr forecast position error in obtaining the "danger area." Note the radius of 30-kt winds is greater on the right side of the storm track -- the dangerous semicircle. In this example the radius to the 30-kt isotach is 200 n mi to the north and 150 n mi to the south of the storm at the current position. The radius to the 30-kt isotach

is forecast to expand to 225 n mi to the north and 175 n mi to the south of the storm center at the 24-hr forecast position. At the 24-hr forecast time the danger area is then 360 n mi (225 plus 135) to the north and 310 n mi (175 plus 135) to the south of the storm.

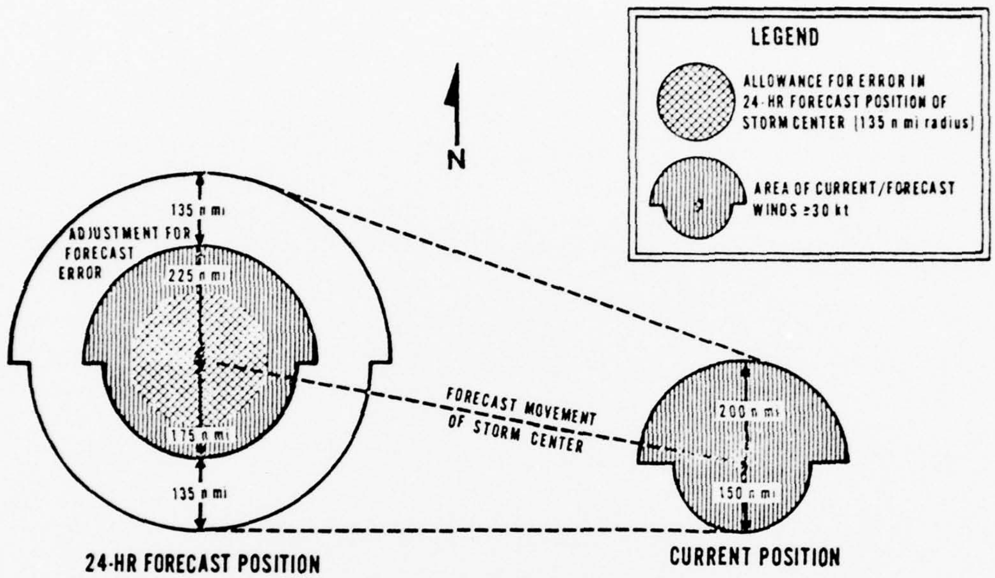

Figure I-6. Method of calculating the danger area for moving typhoons and tropical storms.

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APPENDIX I-A

MEAN MONTHLY AND PART-MONTHLY TROPICAL STORM AND TYPHOON TRACKS FOR THE WESTERN NORTH PACIFIC OCEAN (FROM NAVAIR 50-1C-61)

While it must be realized that tropical storms and typhoons deviate from the mean tracks presented in this appendix, the use of these tracks should be of particular benefit in long range planning. The application of the average tracks to specific short range situations should be avoided. Warnings issued by FWC/JTWC Guam are the immediate source of information on predicted movement.

Table I-A-1 presents the frequency of western North Pacific tropical storms and typhoons by month.

Table I-A-1. WESTPAC tropical storm and typhoon frequency (from NAVAIR 50-1C-61).

WESTERN NORTH PACIFIC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
TROPICAL STORMS	0.2	0.3	0.3	0.2	0.4	0.5	1.2	1.8	1.5	1.0	0.8	0.6	7.5
TYPHOONS	0.3	0.2	0.2	0.7	0.9	1.2	2.7	4.0	4.1	3.3	2.1	0.7	17.8
TROPICAL STORMS AND TYPHOONS	0.4	0.4	0.5	0.9	1.3	1.8	3.9	5.8	5.6	4.3	2.9	1.3	25.3

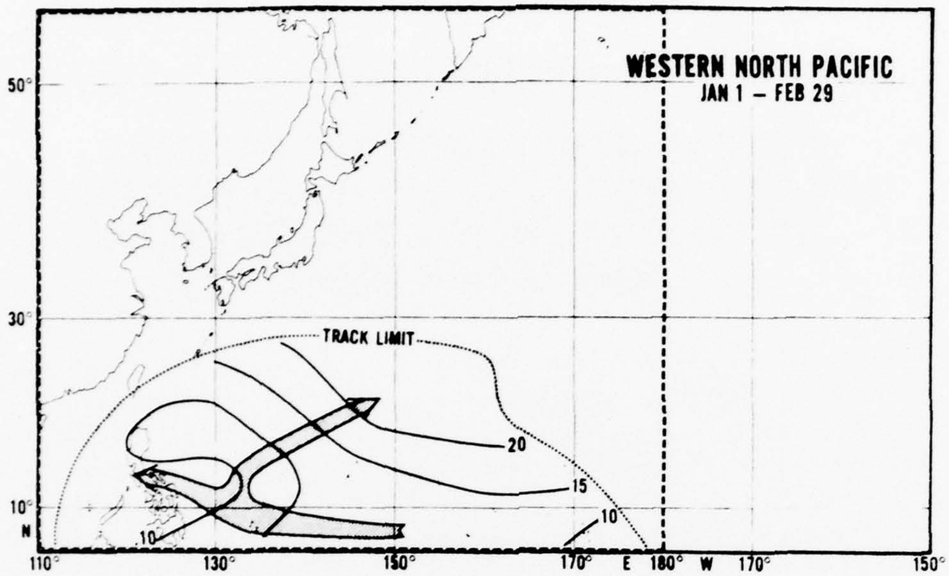

Figure I-A-1. Preferred western North Pacific tropical storm and typhoon tracks (JAN-FEB). Isolines show the average storm speed of movement in knots.

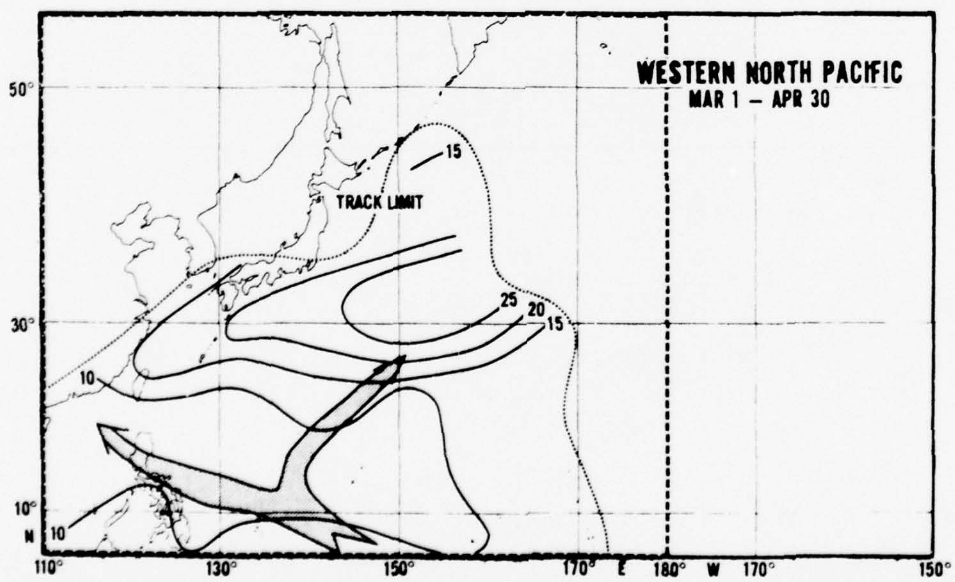

Figure I-A-2. Preferred western North Pacific tropical storm and typhoon tracks (MAR-APR). Isolines show the average storm speed of movement in knots.

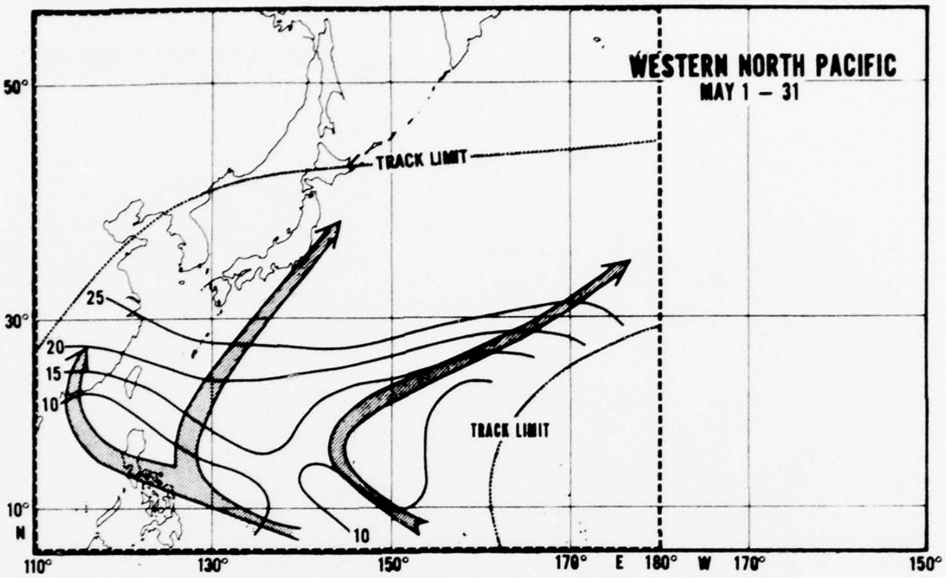

Figure I-A-3. Preferred western North Pacific tropical storm and typhoon tracks (MAY). Isolines show the average storm speed of movement in knots.

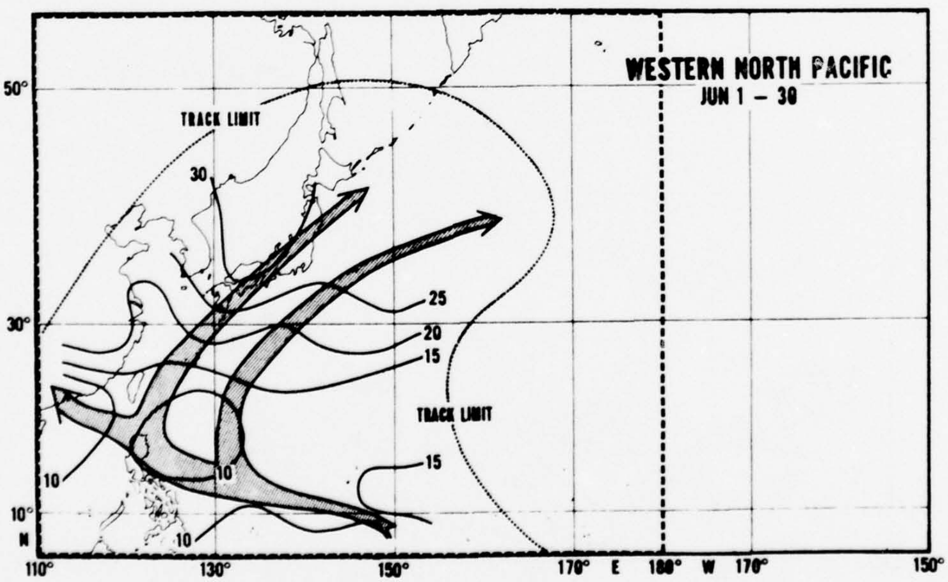

Figure I-A-4. Preferred western North Pacific tropical storm and typhoon tracks (JUN). Isolines show the average storm speed of movement in knots.

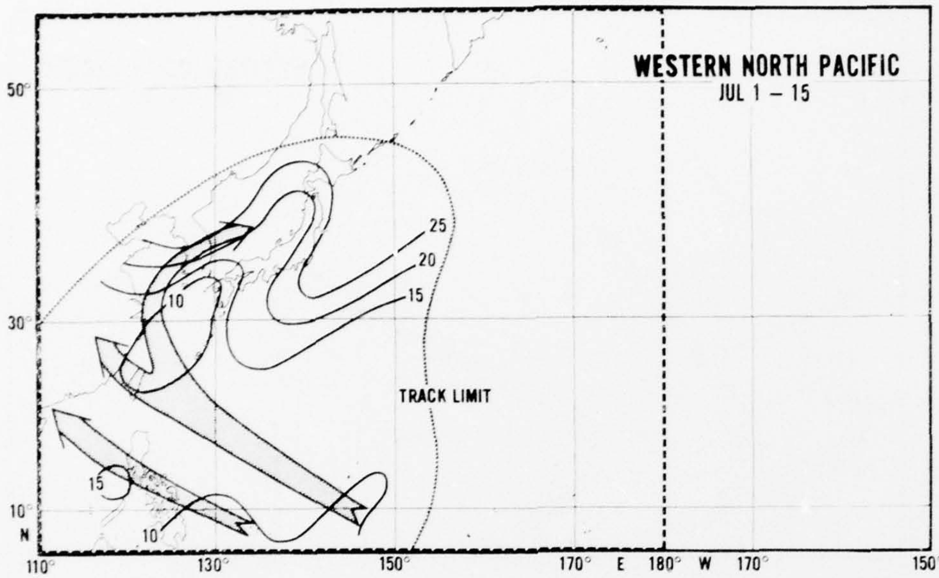

Figure I-A-5. Preferred western North Pacific tropical storm and typhoon tracks (JUL 1-15). Isolines show the average storm speed of movement in knots.

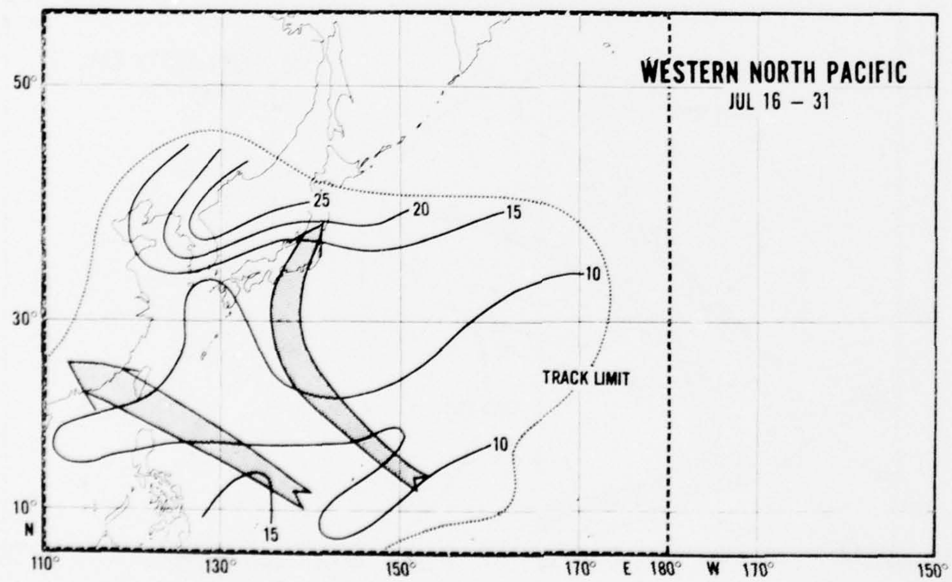

Figure I-A-6. Preferred western North Pacific tropical storm and typhoon tracks (JUL 16-31). Isolines show the average storm speed of movement in knots.

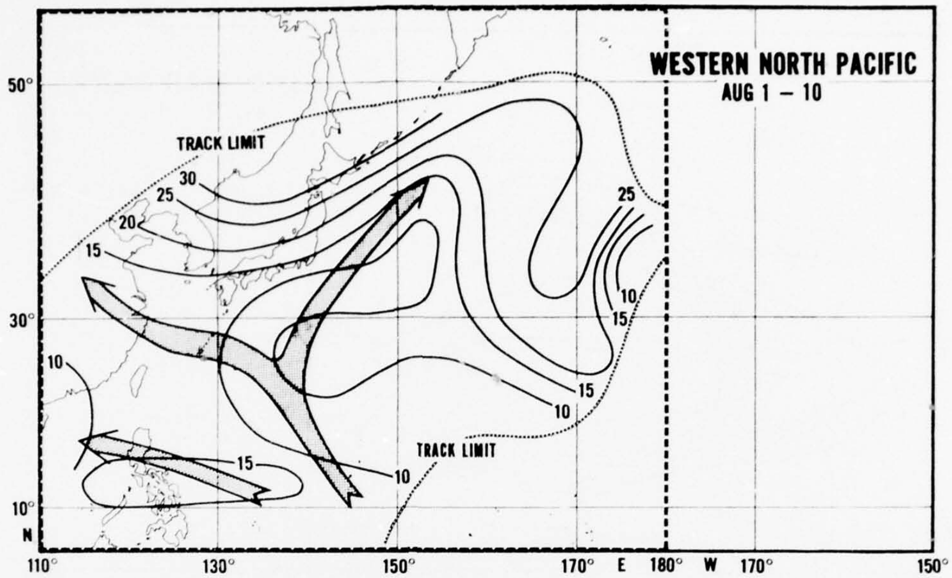

Figure I-A-7. Preferred western North Pacific tropical storm and typhoon tracks (AUG 1-10). Isolines show the average storm speed of movement in knots.

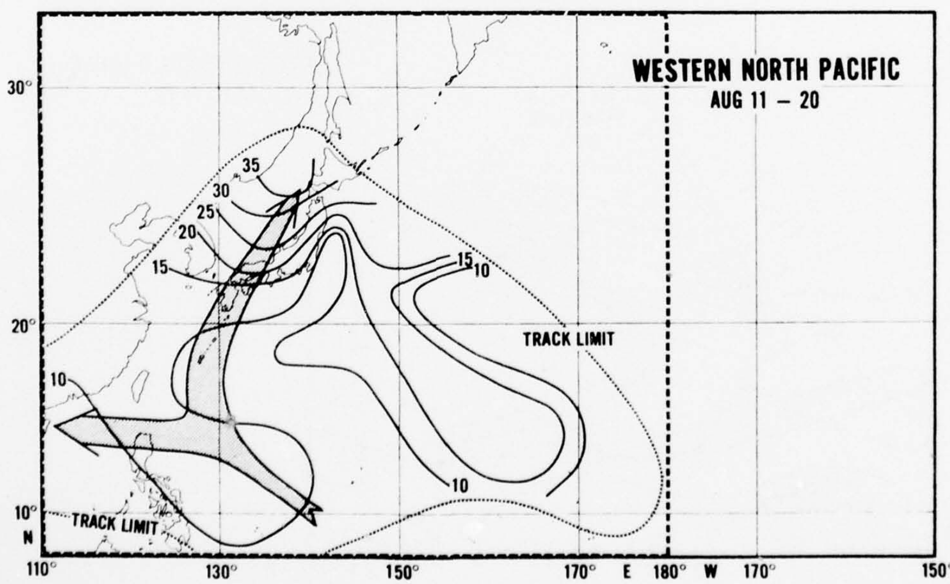

Figure I-A-8. Preferred western North Pacific tropical storm and typhoon tracks (AUG 11-20). Isolines show the average storm speed of movement in knots.

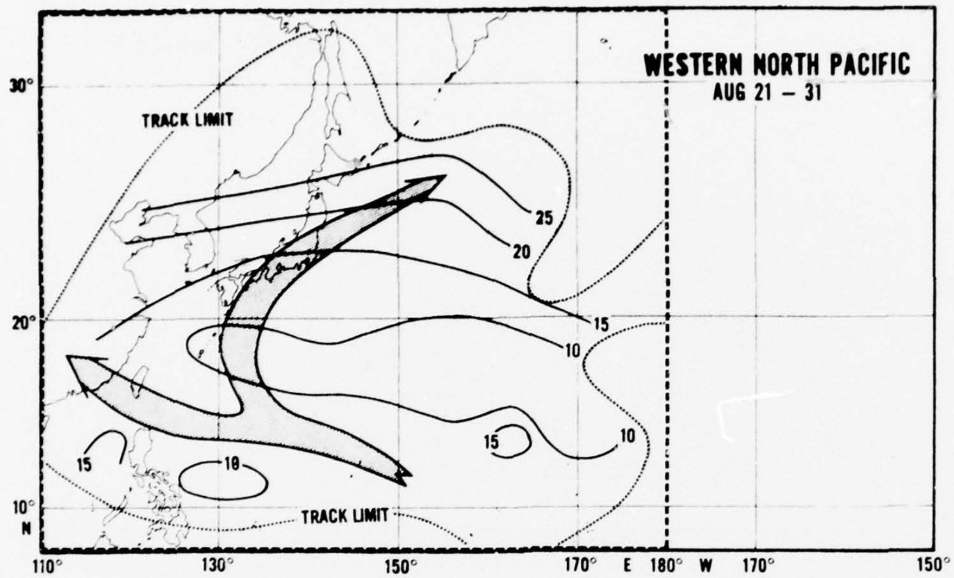

Figure I-A-9. Preferred western North Pacific tropical storm and typhoon tracks (AUG 21-31). Isolines show the average storm speed of movement in knots.

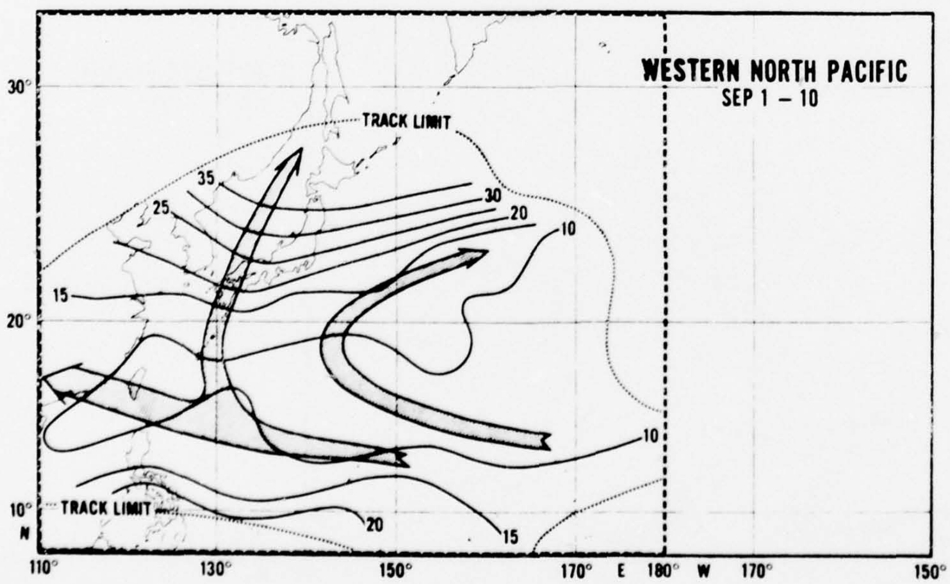

Figure I-A-10. Preferred western North Pacific tropical storm and typhoon tracks (SEP 1-10). Isolines show the average storm speed of movement in knots.

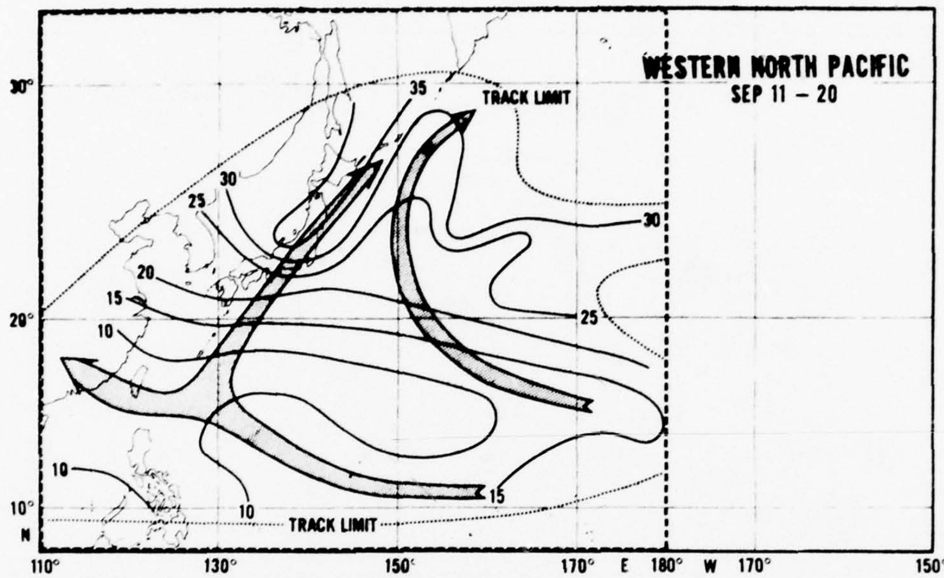

Figure I-A-11. Preferred western North Pacific tropical storm and typhoon tracks (SEP 11-20). Isolines show the average storm speed of movement in knots.

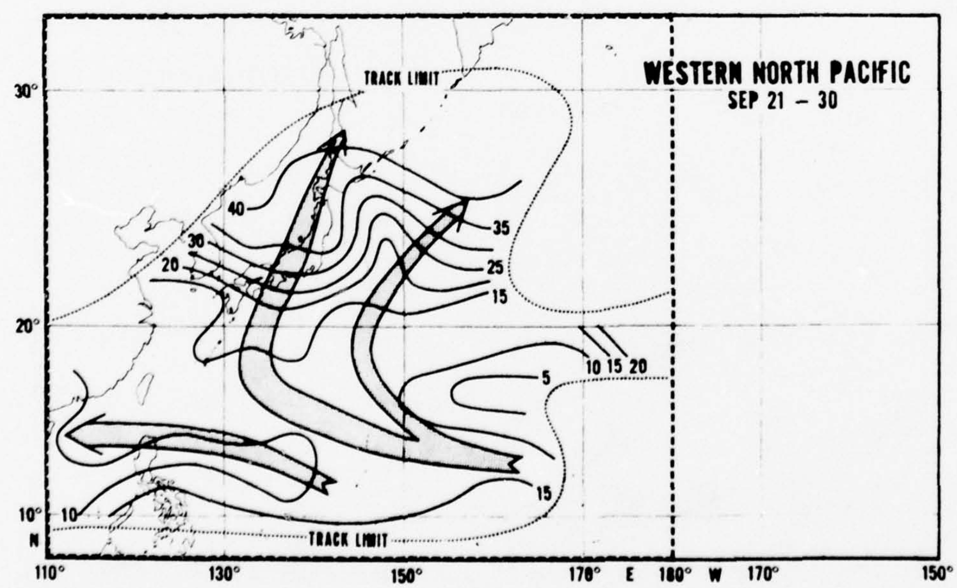

Figure I-A-12. Preferred western North Pacific tropical storm and typhoon tracks (SEP 21-30). Isolines show the average storm speed of movement in knots.

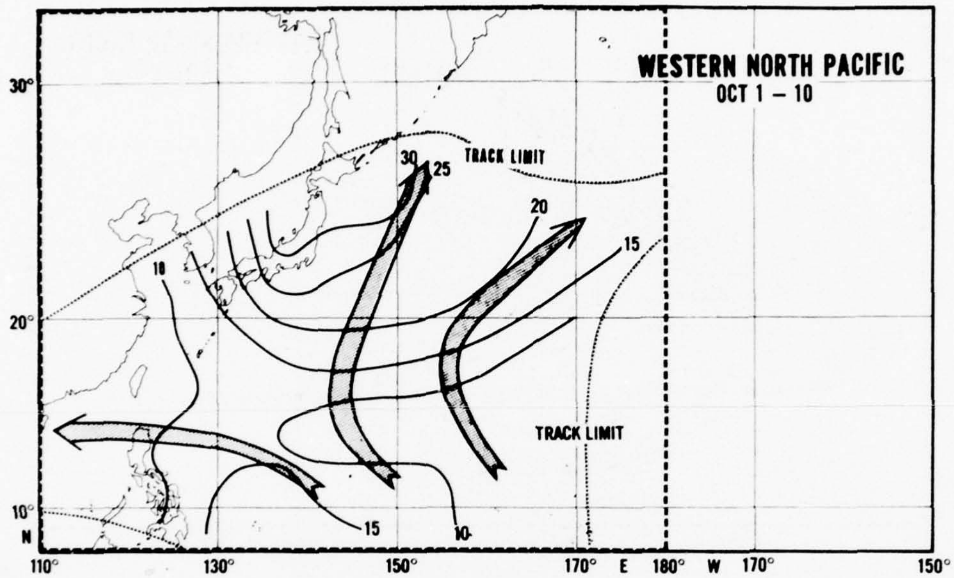

Figure I-A-13. Preferred western North Pacific tropical storm and typhoon tracks (OCT 1-10). Isolines show the average storm speed of movement in knots.

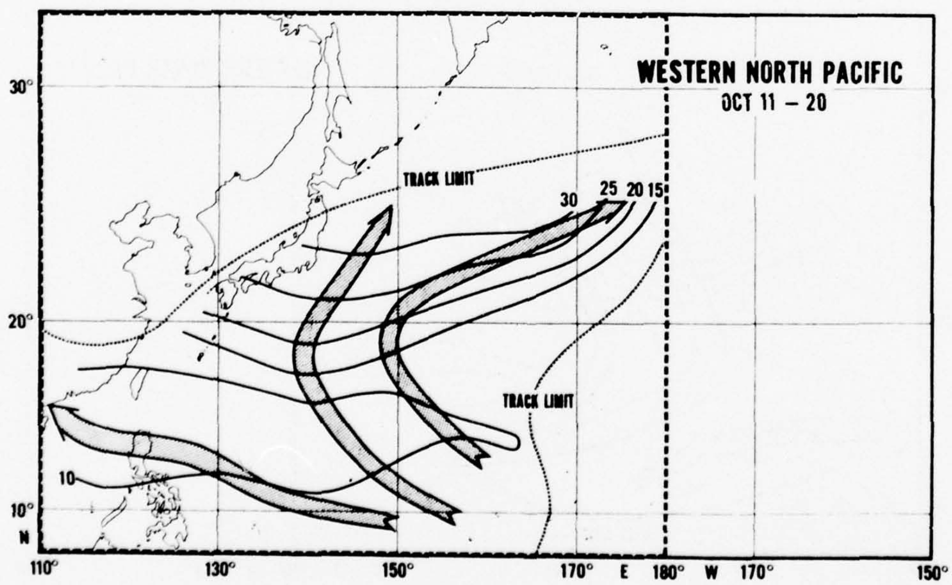

Figure I-A-14. Preferred western North Pacific tropical storm and typhoon tracks (OCT 11-20). Isolines show the average storm speed of movement in knots.

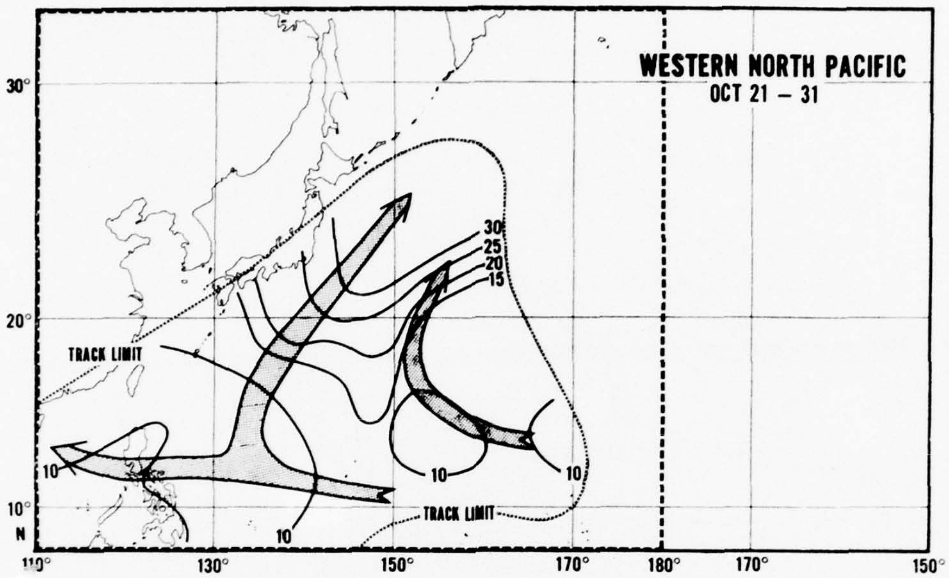

Figure I-A-15. Preferred western North Pacific tropical storm and typhoon tracks (OCT 21-31). Isolines show the average storm speed of movement in knots.

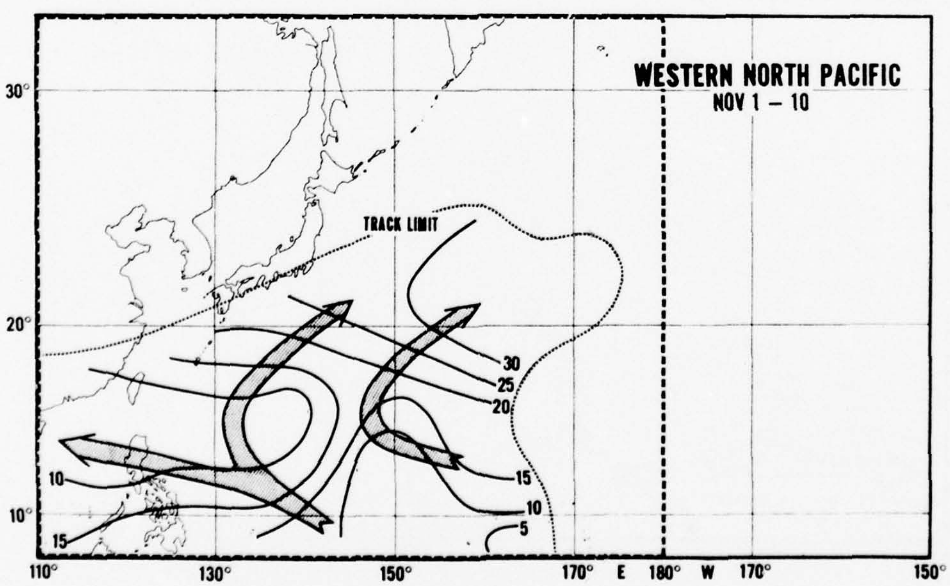

Figure I-A-16. Preferred western North Pacific tropical storm and typhoon tracks (NOV 1-10). Isolines show the average storm speed of movement in knots.

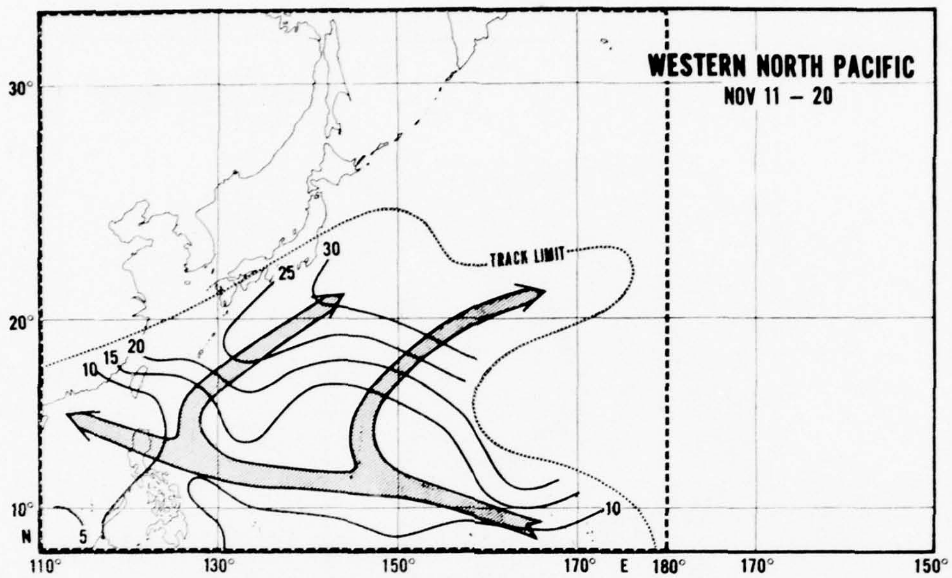

Figure I-A-17. Preferred western North Pacific tropical storm and typhoon tracks (NOV 11-20). Isolines show the average storm speed of movement in knots.

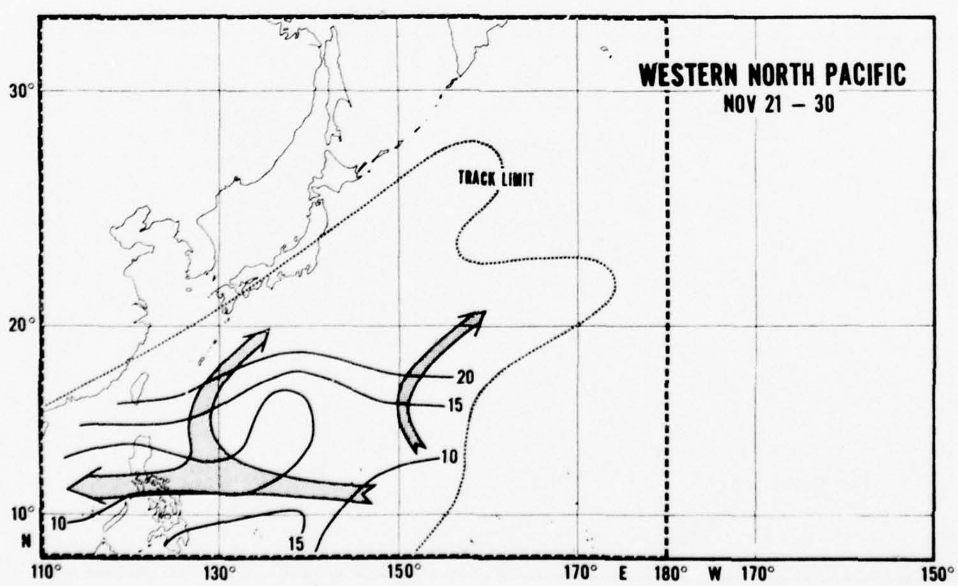

Figure I-A-18. Preferred western North Pacific tropical storm and typhoon tracks (NOV 21-30). Isolines show the average storm speed of movement in knots.

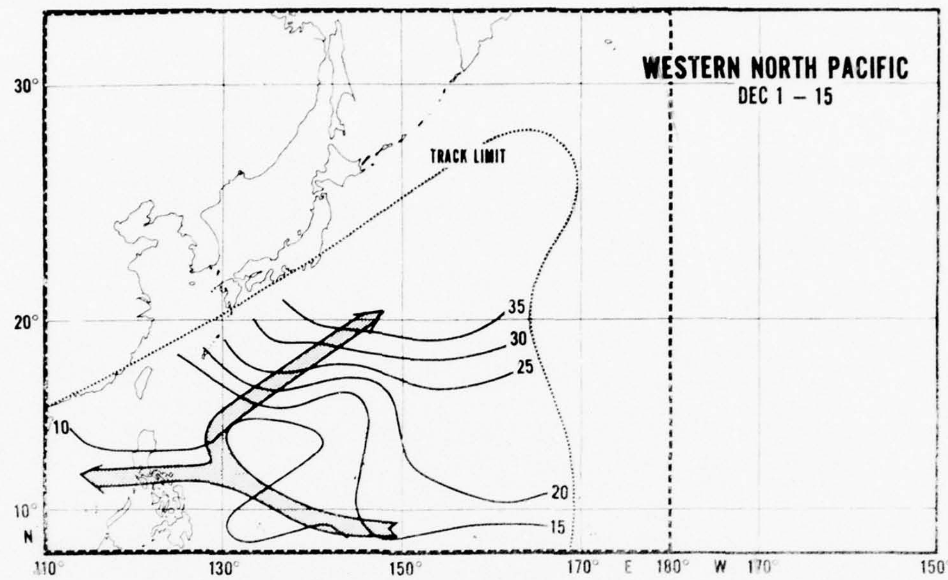

Figure I-A-19. Preferred western North Pacific tropical storm and typhoon tracks (DEC 1-15). Isolines show the average storm speed of movement in knots.

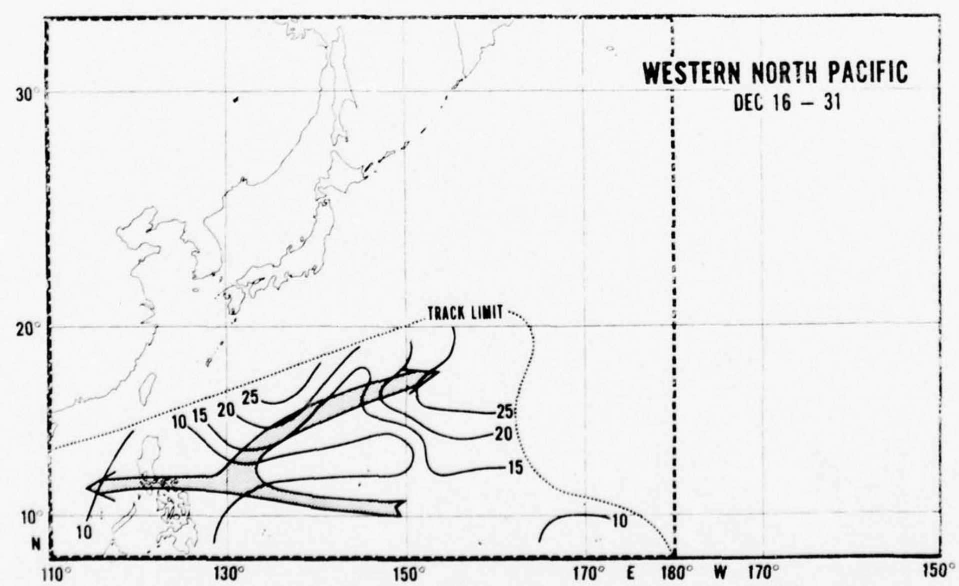

Figure I-A-20. Preferred western North Pacific tropical storm and typhoon tracks (DEC 16-31). Isolines show the average storm speed of movement in knots.

APPENDIX I–B

MEAN MONTHLY AND COMBINED MONTHLY TROPICAL STORM AND CYCLONE TRACKS FOR THE NORTH INDIAN OCEAN (FROM NAVAIR 50–1C–61)

While it must be realized that tropical storms and cyclones deviate from the mean tracks presented in this appendix, the use of these tracks should be of particular benefit in long range planning. The application of the average tracks to specific short range situations should be avoided. Warnings issued by FWC/JTWC Guam are the immediate source of information on predicted movement.

Table I-B-1 presents the frequency of North Indian Ocean tropical storms and cyclones by month.

Table I-B-1. North Indian Ocean tropical storm and cyclone frequency (from NAVAIR 50-1C-61).

NORTH INDIAN OCEAN	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
TROPICAL STORMS	0.1			0.1	0.3	0.5	0.5	0.4	0.4	0.6	0.5	0.3	3.5
CYCLONES				0.1	0.5	0.2	0.1		0.1	0.4	0.6	0.2	2.2
TROPICAL STORMS AND CYCLONES	0.1		0.1	0.3	0.7	0.7	0.6	0.4	0.5	0.5	1.1	0.5	5.7

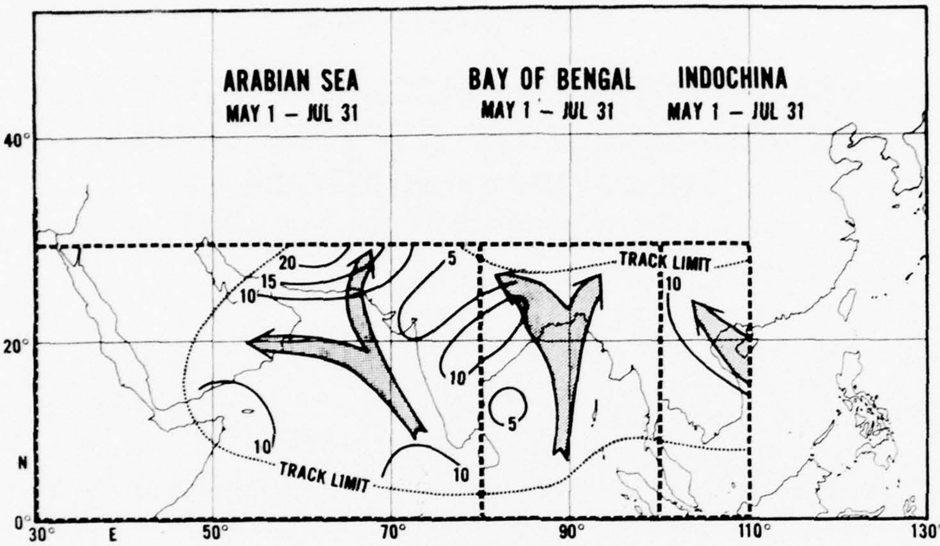

Figure I-B-1. Preferred North Indian Ocean tropical storm and cyclone tracks (May 1-Jul 31). Isolines show the average storm speed of movement in knots.

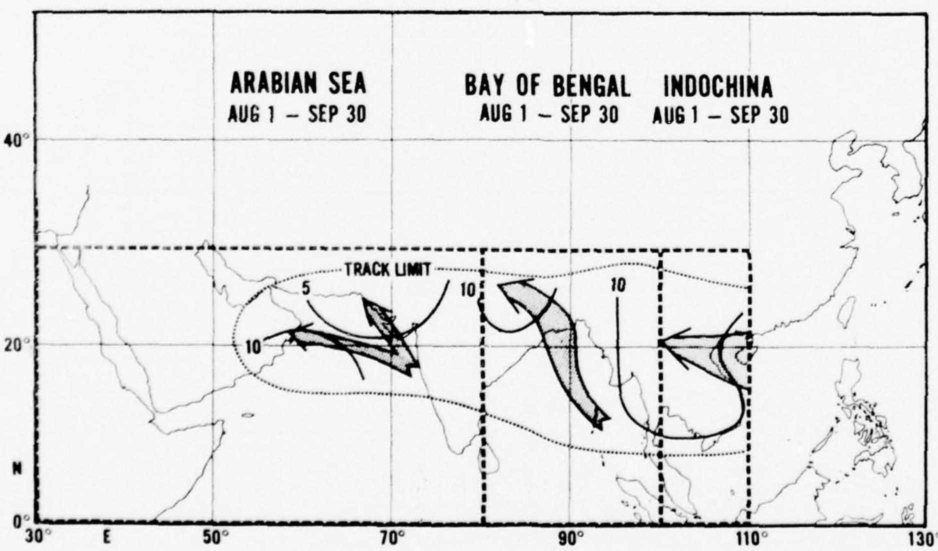

Figure I-B-2. Preferred North Indian Ocean tropical storm and cyclone tracks (Aug 1-Sep 30). Isolines show the average storm speed of movement in knots.

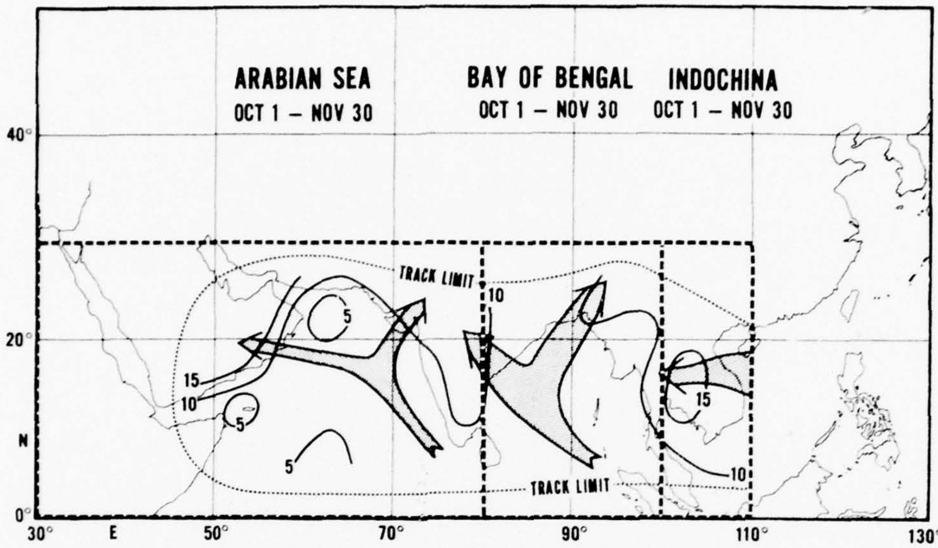

Figure I-B-3. Preferred North Indian Ocean tropical storm and cyclone tracks (Oct 1-Nov 30). Isolines show the average storm speed of movement in knots.

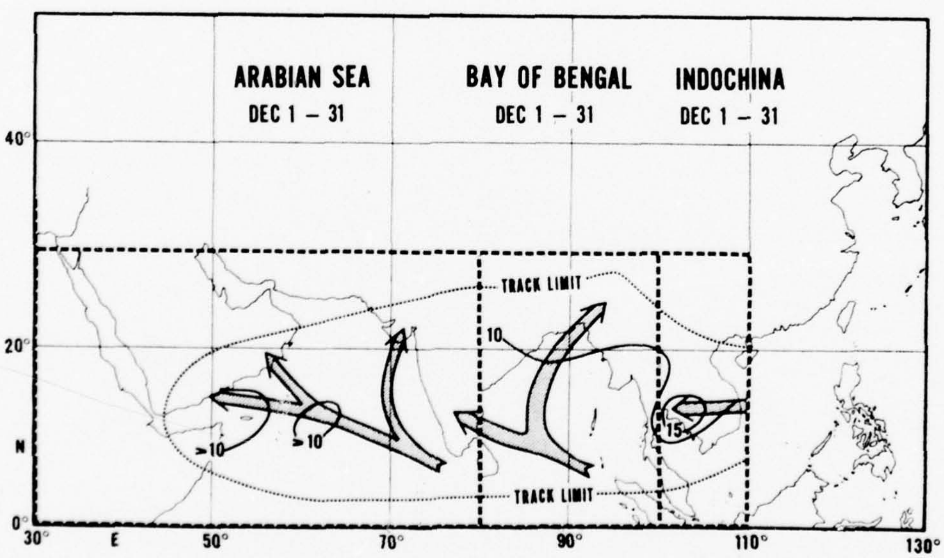

Figure I-B-4. Preferred North Indian Ocean tropical storm and cyclone tracks (Dec 1-31). Isolines show the average storm speed of movement in knots.

APPENDIX I—C

MEAN MONTHLY AND PART MONTHLY TROPICAL STORM AND HURRICANE TRACKS FOR THE SOUTHWEST INDIAN OCEAN (FROM NAVAIR 50—1C—61)

While it must be realized that tropical storms and hurricanes deviate from the mean tracks presented in this appendix, the use of these tracks should be of particular benefit in long range planning. The application of the average tracks to specific short range situations should be avoided. Warnings issued by FWC/JTWC Guam are the immediate source of information on predicted movement.

Table I-C-1 presents the frequency of Southwest Indian Ocean tropical storms and hurricanes by month.

Table I-C-1. Southwest Indian Ocean tropical storm and hurricane frequency (from NAVAIR 50-1C-61).

SOUTHWEST INDIAN OCEAN	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
TROPICAL STORMS	2.0	2.2	1.7	0.6	0.2					0.3	0.3	0.8	7.4
HURRICANES	1.3	1.1	0.8	0.4								0.5	3.8
TROPICAL STORMS AND HURRICANES	3.2	3.3	2.5	1.1	0.2					0.3	0.4	1.4	11.2

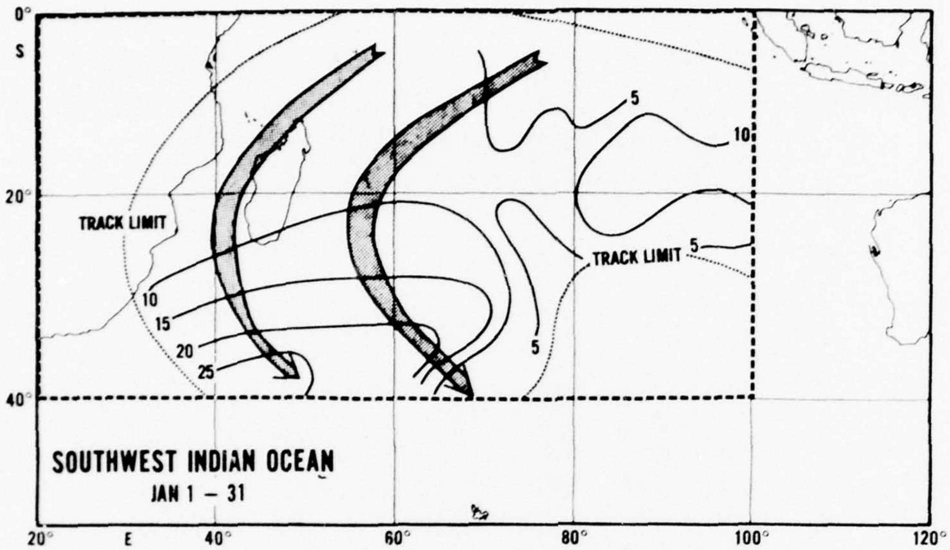

Figure I-C-1. Preferred Southwest Indian Ocean tropical storm and hurricane tracks (Jan 1-31). Isolines show the average storm speed of movement in knots.

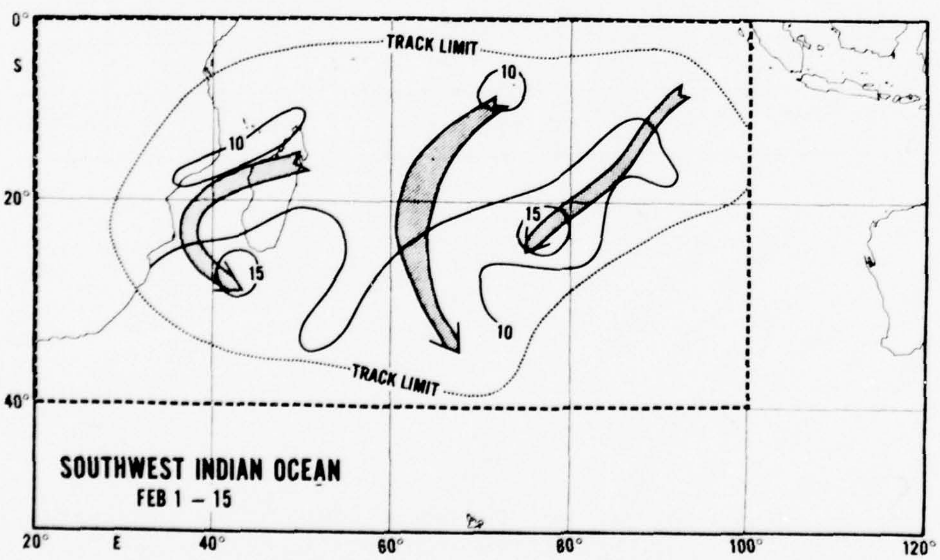

Figure I-C-2. Preferred Southwest Indian Ocean tropical storm and hurricane tracks (Feb 1-15). Isolines show the average storm speed of movement in knots.

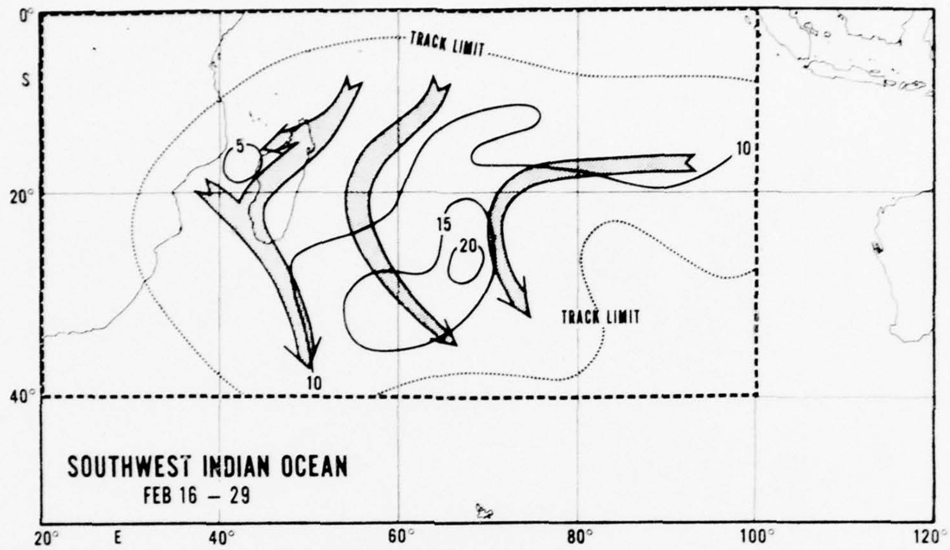

Figure I-C-3. Preferred Southwest Indian Ocean tropical storm and hurricane tracks (Feb 16-29). Isolines show the average storm speed of movement in knots.

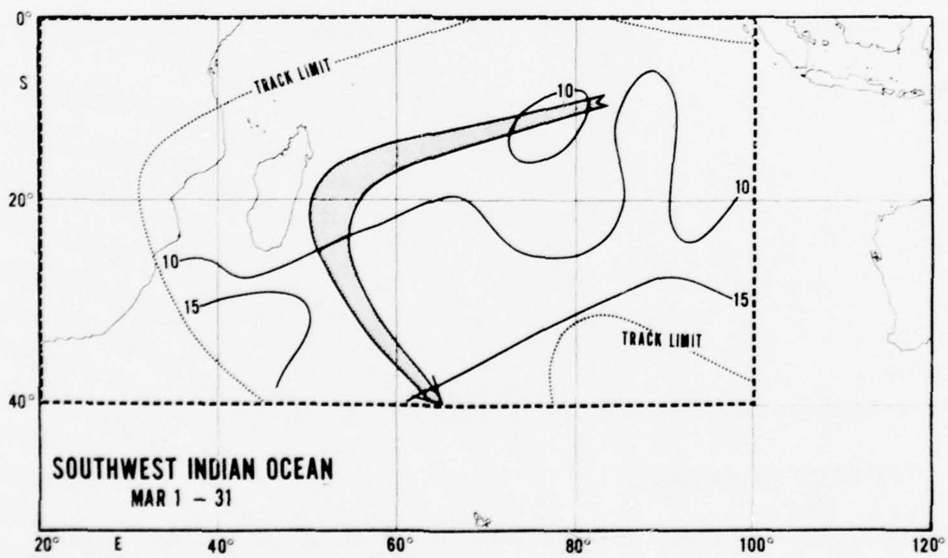

Figure I-C-4. Preferred Southwest Indian Ocean tropical storm and hurricane tracks (Mar 1-31). Isolines show the average storm speed of movement in knots.

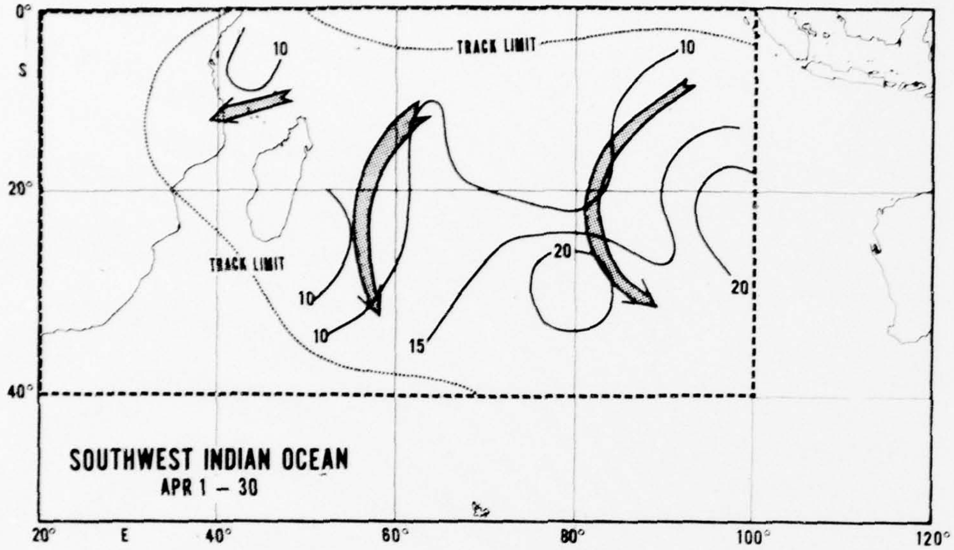

Figure I-C-5. Preferred Southwest Indian Ocean tropical storm and hurricane tracks (Apr 1-30). Isolines show the average storm speed of movement in knots.

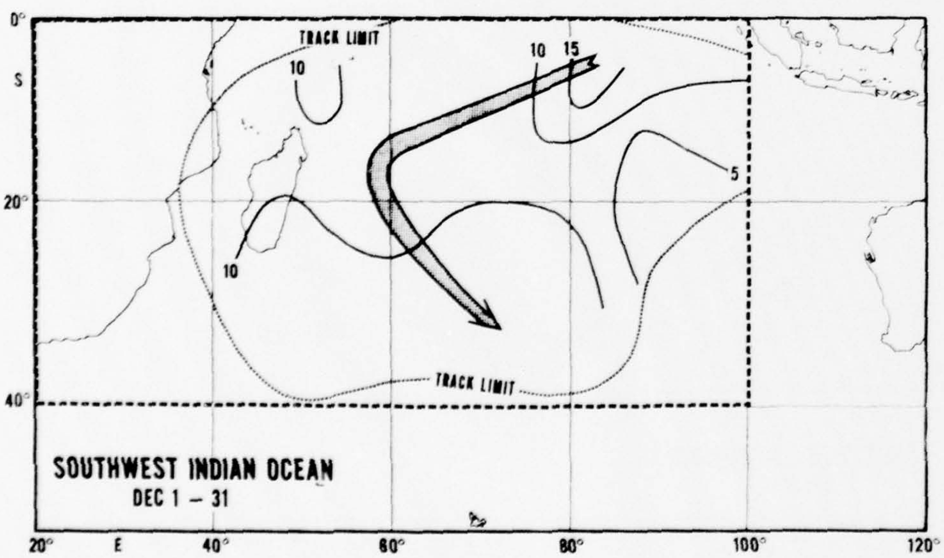

Figure I-C-6. Preferred Southwest Indian Ocean tropical storm and hurricane tracks (Dec 1-31). Isolines show the average storm speed of movement in knots.

APPENDIX I—D

MEAN MONTHLY AND PART MONTHLY TROPICAL STORM AND HURRICANE TRACKS FOR THE SOUTHWEST PACIFIC OCEAN AND AUSTRALIAN AREA (FROM NAVAIR 50—1C—61)

While it must be realized that tropical storms and hurricanes deviate from the mean tracks presented in this appendix, the use of these tracks should be of particular benefit in long range planning. The application of the average tracks to specific short range situations should be avoided. Warnings issued by FWC/JTWC Guam are the immediate source of information on predicted movement.

Table I-D-1 presents the frequency of Southwest Pacific and Australian area tropical storms and hurricanes by month.

Table I-D-1. Southwest Pacific and Australian area tropical storm and hurricane frequency (from NAVAIR 50-1C-61).

SOUTHWEST PACIFIC AND AUSTRALIAN AREA	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
TROPICAL STORMS	2.7	2.8	2.4	1.3	0.3	0.2				0.1	0.4	1.5	10.9
HURRICANES	0.7	1.1	1.3	0.3			0.1	0.1			0.3	0.5	3.8
TROPICAL STORMS AND HURRICANES	3.4	4.1	3.7	1.7	0.3	0.2	0.1	0.1		0.1	0.7	2.0	14.8

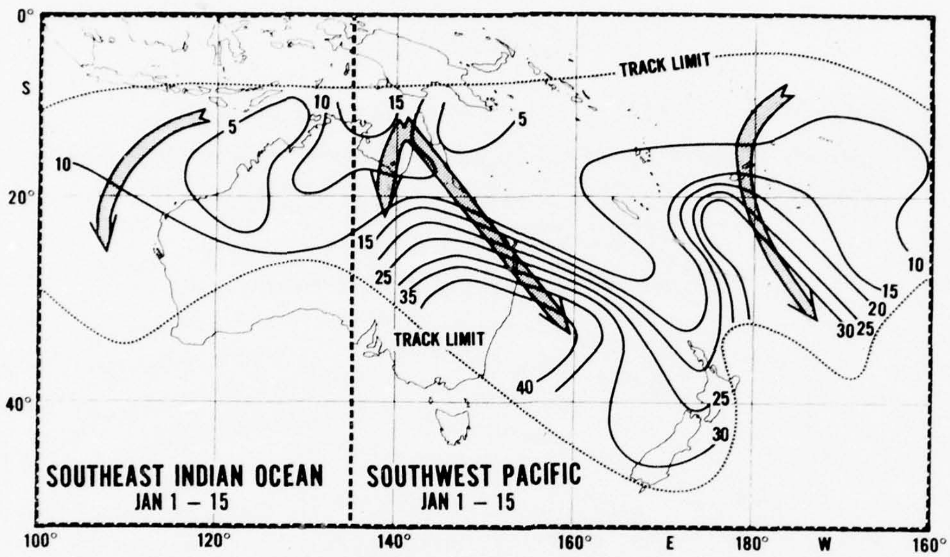

Figure I-D-1. Preferred Southwest Pacific and Australian area tropical storm and hurricane tracks (Jan 1-15). Isolines show the average storm speed of movement in knots.

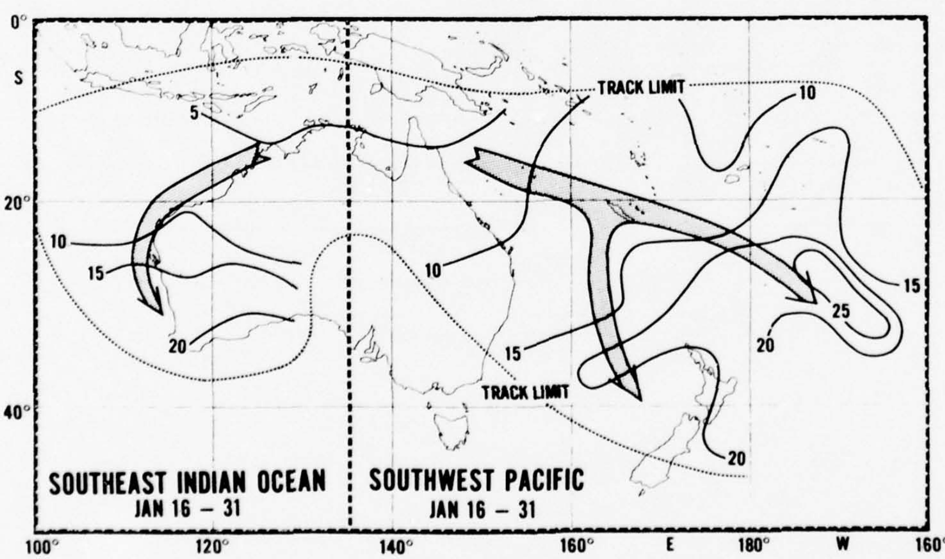

Figure I-D-2. Preferred Southwest Pacific and Australian area tropical storm and hurricane tracks (Jan 16-31). Isolines show the average storm speed of movement in knots.

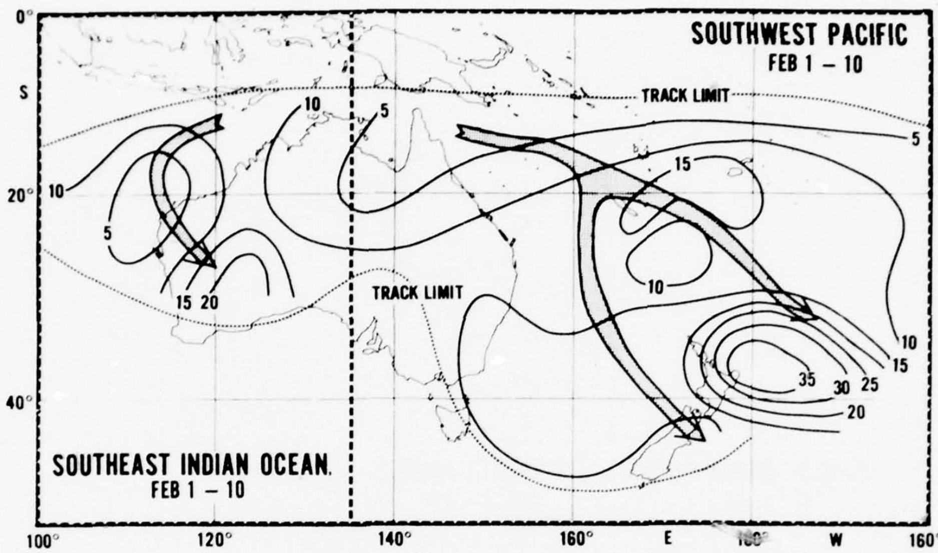

Figure I-D-3. Preferred Southwest Pacific and Australian area tropical storm and hurricane tracks (Feb 1-10). Isolines show the average storm speed of movement in knots.

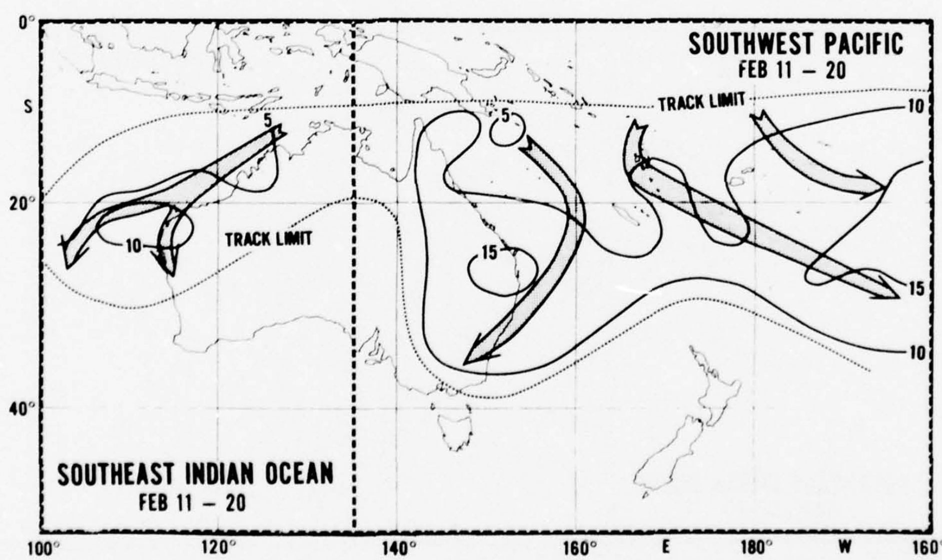

Figure I-D-4. Preferred Southwest Pacific and Australian area tropical storm and hurricane tracks (Feb 11-20). Isolines show the average storm speed of movement in knots.

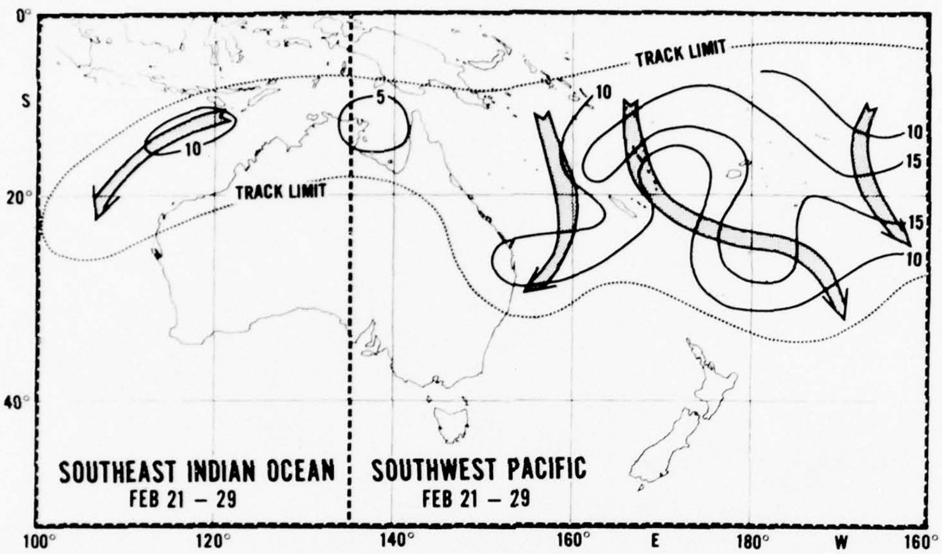

Figure I-D-5. Preferred Southwest Pacific and Australian area tropical storm and hurricane tracks (Feb 21-29). Isolines show the average storm speed of movement in knots.

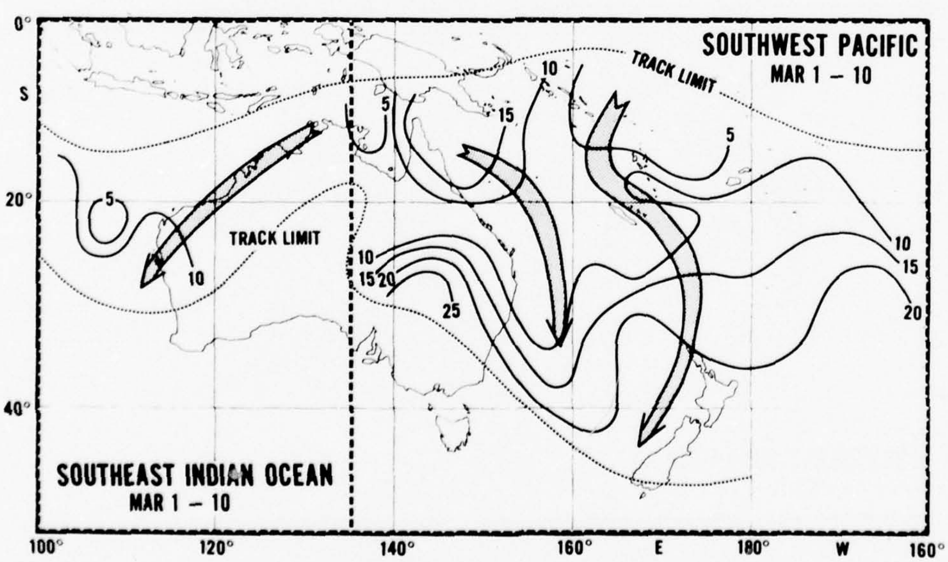

Figure I-D-6. Preferred Southwest Pacific and Australian area tropical storm and hurricane tracks (Mar 1-10). Isolines show the average storm speed of movement in knots.

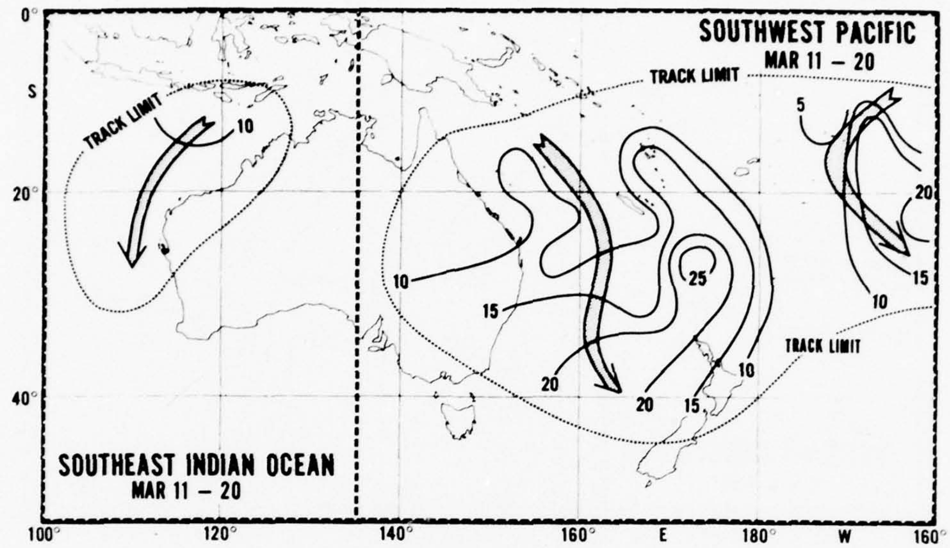

Figure I-D-7. Preferred Southwest Pacific and Australian area tropical storm and hurricane tracks (Mar 11-20). Isolines show the average storm speed of movement in knots.

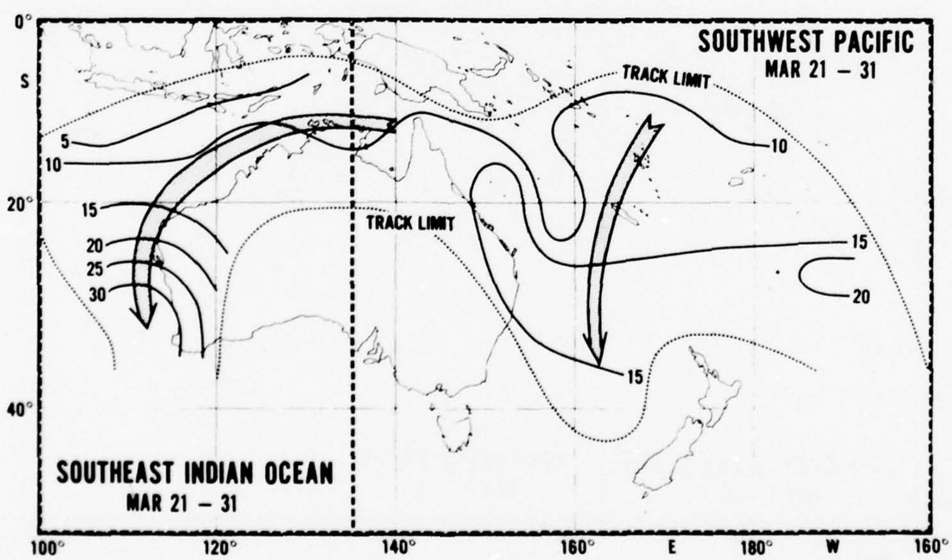

Figure I-D-8. Preferred Southwest Pacific and Australian area tropical storm and hurricane tracks (Mar 21-31). Isolines show the average storm speed of movement in knots.

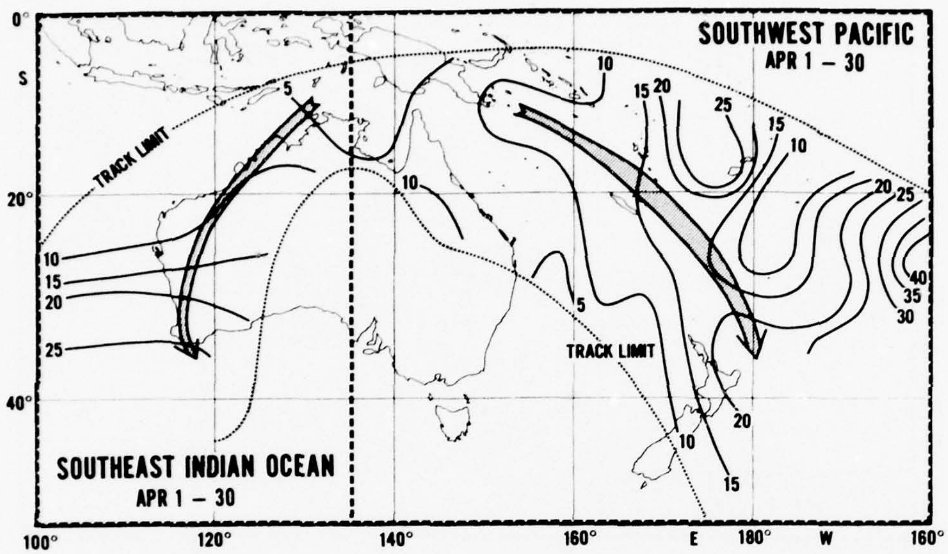

Figure I-D-9. Preferred Southwest Pacific and Australian area tropical storm and hurricane tracks (Apr 1-30). Isolines show the average storm speed of movement in knots.

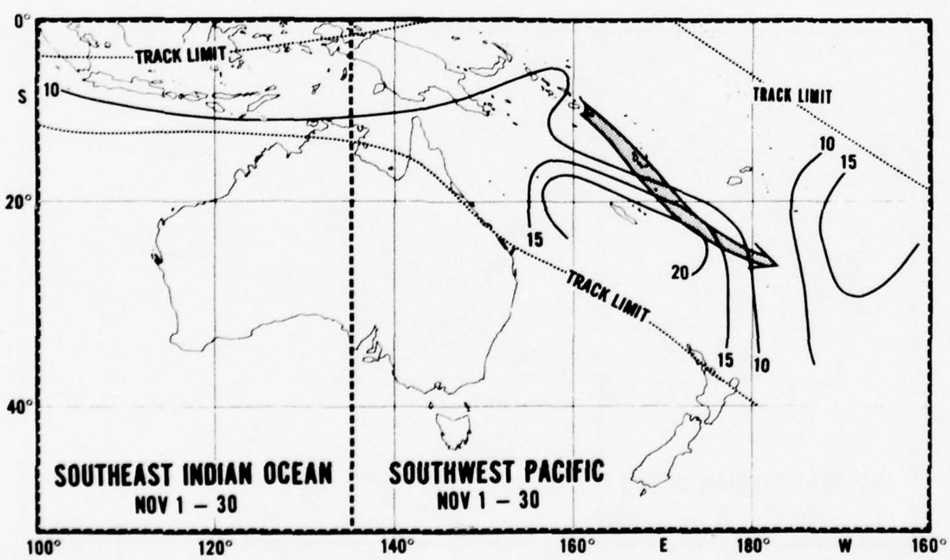

Figure I-D-10. Preferred Southwest Pacific and Australian area tropical storm and hurricane tracks (Nov 1-30). Isolines show the average storm speed of movement in knots.

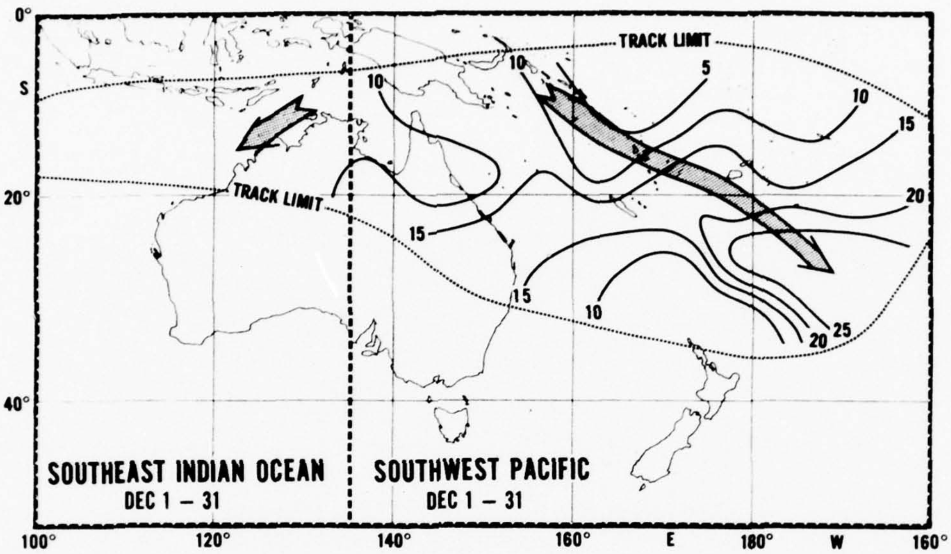

Figure I-D-11. Preferred Southwest Pacific and Australian area tropical storm and hurricane tracks (Dec 1-31). Isolines show the average storm speed of movement in knots.

SECTION II - CONTENTS

II GUAM

1. GENERAL

Guam, the southernmost island in the Mariana Islands group, is located approximately 1300 n mi east of the Philippines. Guam is a relatively flat island with only a few points reaching over 1000 feet above sea level (see Figure II-1).

Agana is the capital city of Guam, with Apra Harbor as its commercial and military port. While other anchorages are available, Apra Harbor is the only port on Guam suitable for use by U. S. Navy or Military Sealift Command vessels.

A detailed study of the coast and bays of Guam is included in Hydrographic Office Publication No. 82 (formerly 165A). For specific comments on coastal features the reader is referred to the above mentioned publication.

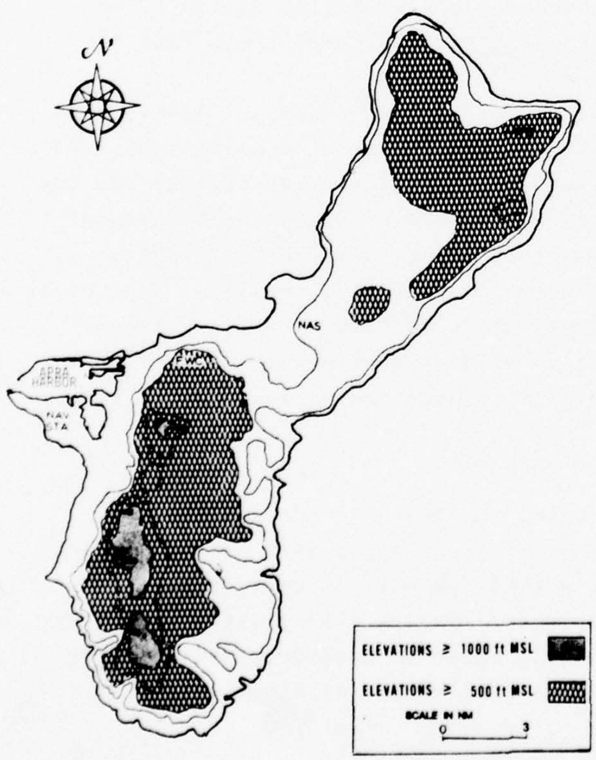

Figure II-1. Topographical map of Guam.

2. APRA HARBOR

SUMMARY

There are no aspects of Apra Harbor that recommend it as a typhoon haven. Typhoon Karen (November, 1962) gave Apra Harbor sustained winds of 150 kt! The surrounding topography is low and does not provide an extensive wind break. The harbor entrance is open to the west and is in close proximity to the berths and moorings in the outer harbor. Consequently, westerly winds and seas associated with the typhoon passage have a devastating effect within the harbor.

In the past, all U. S. Navy ships capable have sortied from the harbor upon the approach of a typhoon. Additionally, the Port Operations Officer desires that ships not use Apra Harbor as a typhoon haven since the harbor's and NAVSHIPREPFAC Guam's yard and service craft occupy virtually all desirable berths in the harbor during typhoon conditions.

2.1 GENERAL DESCRIPTION OF APRA HARBOR

Apra Harbor, which consists of an inner and outer harbor, is an improved natural harbor located on the southwest coast of the island of Guam. Figure II-2 shows the general harbor layout. Orote Peninsula which projects 3.5 n mi northwestward from the coast forms the southern boundary of the harbor. The harbor is bounded on the north by a breakwater that is partially man made and extends 15 ft (average) above mean sea level.

The entrance to Apra Harbor is 500 yards wide and in excess of 100 ft deep. Apra Harbor is extensive and contains a substantial number of mooring buoys and piers. The outer harbor affords a large number of deep water anchorages and the holding capability is considered excellent. It should be noted that the outer harbor contains several shoal or reef areas that are clearly marked. While these areas pose only a limited threat to normal operations, they must be a major consideration should maneuvering be required during periods of heavy weather.

The low hills to the east of Apra Harbor provide a windbreak for easterly winds. However, Apra Harbor should by no means be considered a sheltered port.

2.2 TROPICAL CYCLONE CLIMATOLOGY FOR APRA HARBOR

Severe tropical cyclones can occur during any month of the year in the western North Pacific area. However, the majority of those that pose a "threat" to Guam (any tropical cyclone approaching within 180 n mi is considered a "threat") occur during the months June-December. Figure II-3 gives the monthly summary of threat situations by 5-day periods, based on June-December data for the 27 years, 1947 to 1973. Note that the maximum number of storms occur in the months July through November.

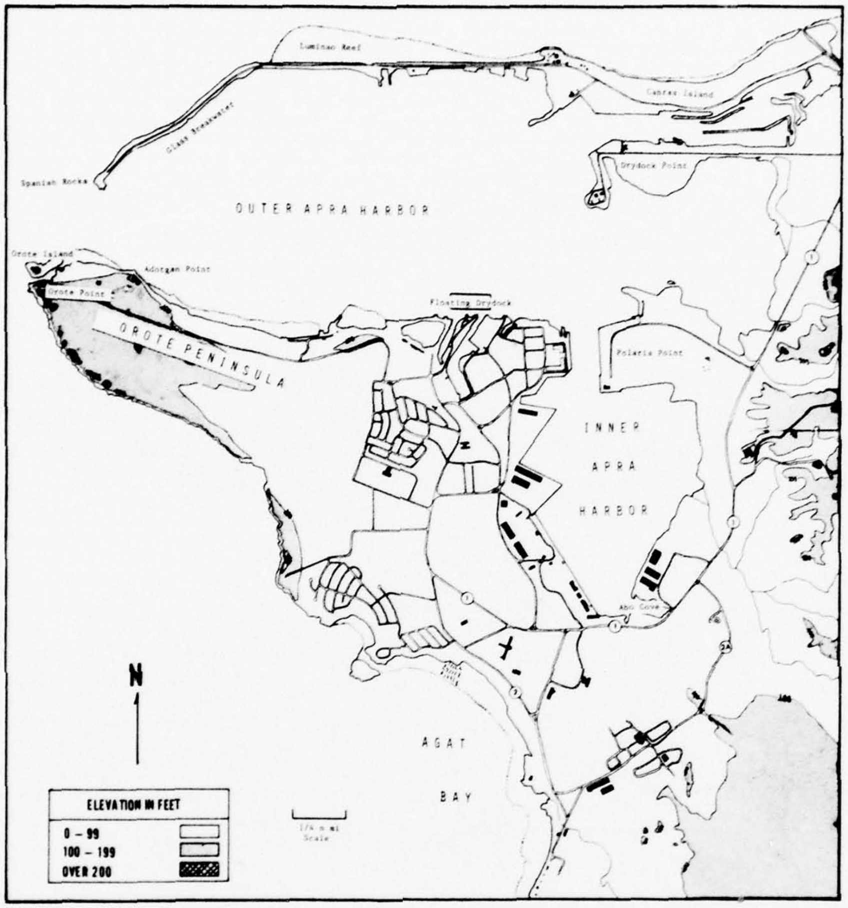

Figure II-2. Apra Harbor

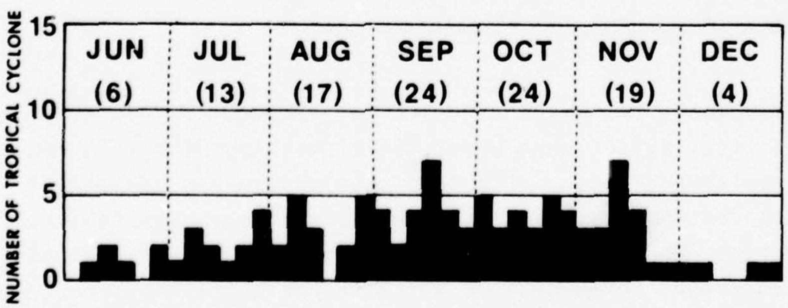

Figure II-3. Frequency distribution of the number of tropical cyclones that passed within 180 n mi of Guam (June-December, 1947-1973). Subtotals are based on 5-day periods and the numbers in parentheses are the monthly totals.

GUAM
(APRA HARBOR)

In Figure II-4 these "threat" tropical cyclones are displayed according to the compass octant from which they approached Guam. The circled numbers indicate the total that approached from an individual octant. The numbers in parentheses give this as a percentage of the total. It is readily seen that a majority of storms approach from the east and southeast.

Approximately 4 tropical cyclones each year will pose a threat to Guam. Since Guam is in the development area for WESTPAC tropical cyclones, many of these storms are in the formative stages of their life cycle and have not, as yet, achieved typhoon intensity. Of the 107 tropical cyclones that approached or developed within 180 n mi of Guam in the period June-December, 1947 to 1973, the point where these storms attained tropical storm intensity ($\geq$34 kt) is in many cases to the west of Guam (see Figure II-5). In fact approximately 50% reach tropical storm intensity after the Closest Point of Approach (CPA) (assuming most were moving on a general east to west track).

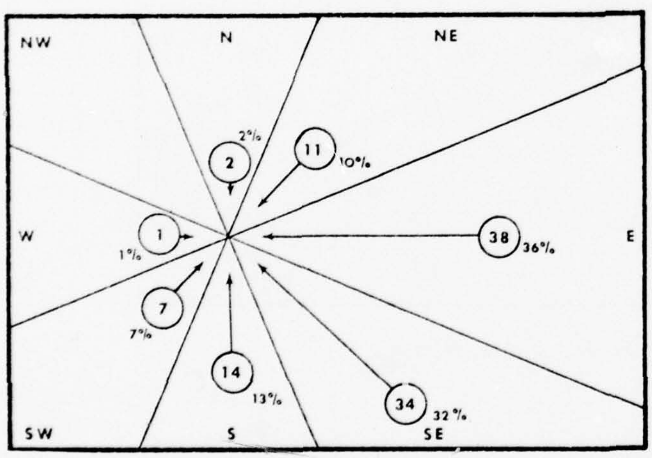

Figure II-4. Direction of approach to Guam of the tropical cyclones (June-December, 1947-1973) which passed within 180 n mi of Guam. Circled numbers indicate the number that approached from each octant. The numbers in parentheses are the percentage of the total sample (107) that approached from that octant.

Figure II-6 shows the point at which the tropical cyclones reached typhoon intensity ($\geq$64 kt). Notice that about 75% of the typhoons attained typhoon intensity to the west of Guam. The fact that a large percentage of storms are not of "typhoon" intensity at CPA must not allow the reader to develop a false sense of security. While a storm with winds of 50-60 kt is obviously not a typhoon, the potential for damage is still very significant.

A tropical cyclone in the vicinity of Guam will, on the average, intensify 15-20 kt/24 hr, but the danger always exists that the storm will rapidly intensify by 40-50 kt/24 hr (5-10% probability for this region).

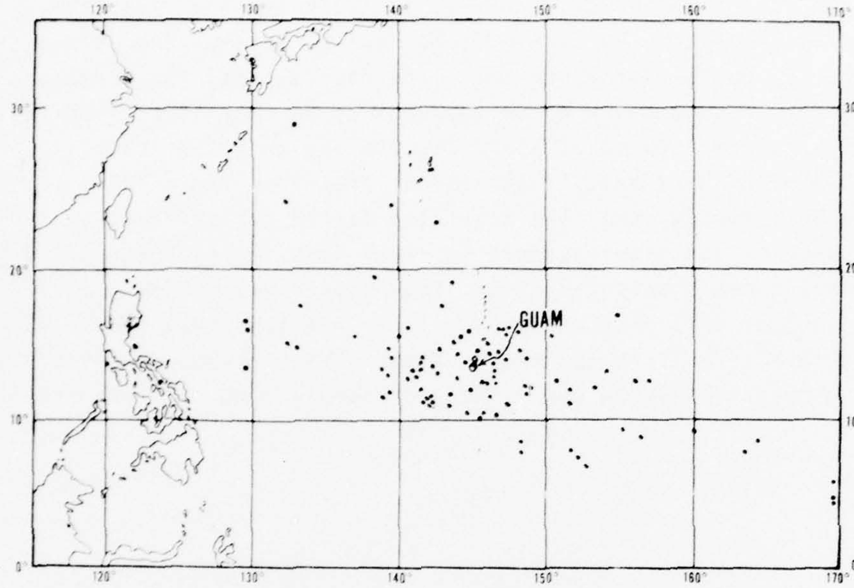

Figure II-5. Initial point of attainment of tropical storm intensity (≥34 kt) for 107 tropical cyclones passing within 180 n mi of Guam (June-December, 1947-1973). Since 7 tropical depressions did not achieve the above criteria, only 100 positions are plotted.

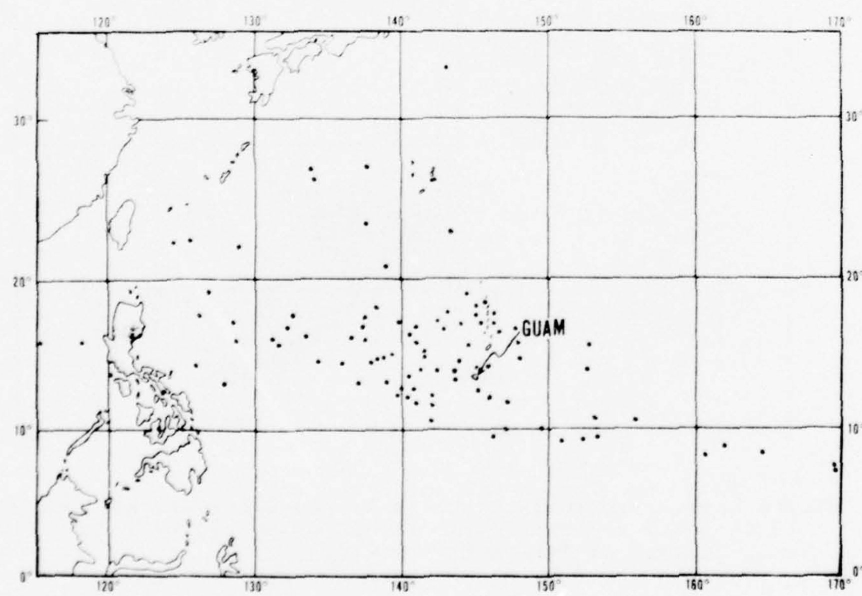

Figure II-6. Initial point of attainment of typhoon intensity (≥64 kt) for 107 tropical cyclones passing within 180 n mi of Guam (June-December, 1947-1973). Since 16 tropical cyclones did not achieve the above criteria, only 91 positions are plotted.

GUAM
(APRA HARBOR)

Figures II-7 through II-13 present the percentage of tropical cyclones that have passed within 180 n mi of Guam (can be interpreted as a probability of threat) for the months June-December. The dashed lines represent approximate approach times to Guam based on an approach speed of 8-12 kt. For example, in Figure II-7 a storm located at 150°E and 8°N has an 80% probability of passing within 180 n mi of Guam and, if its speed remains in the 8-12 kt range, it will reach Guam in slightly over 1½-2 days (the faster the speed of an individual storm the shorter the time required to reach Guam). For the remainder of this section, only those tropical cyclones that passed within 180 n mi (3° of latitude) of Guam will be considered. It is realized that storms which did not approach within this limit may have affected the harbor. However, a criterion had to be chosen that would limit the data sample; 180 n mi was the limit selected.

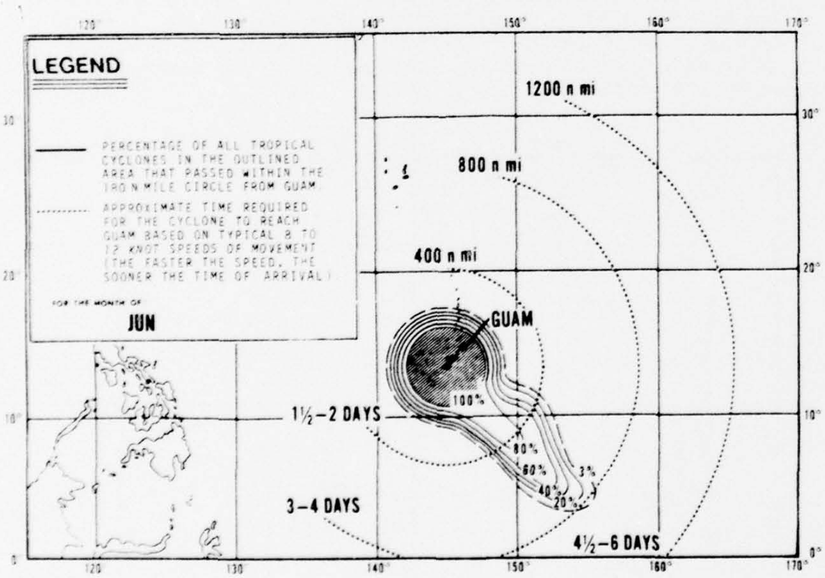

Figure II-7. Probability that a tropical cyclone will pass within 180 n mi (shaded circle) of Guam for the month of June. (Based on data from 1947-1973.)

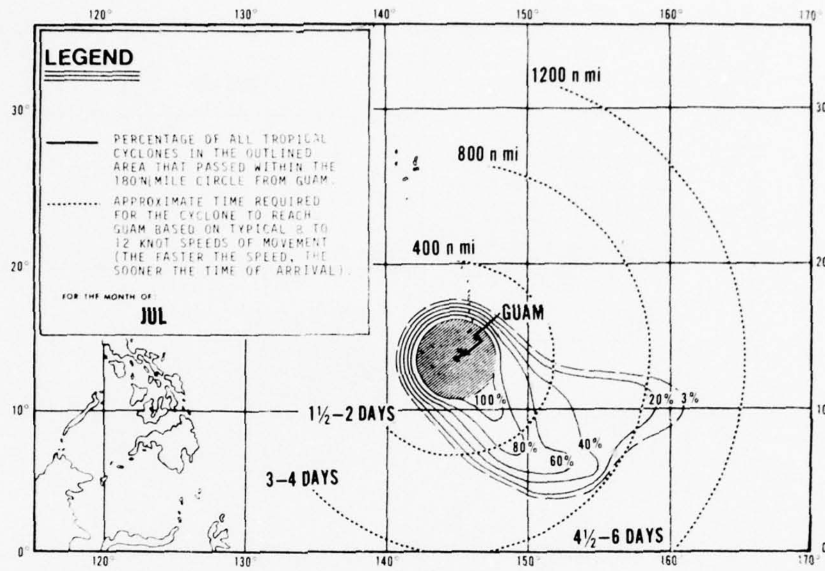

Figure II-8. Probability that a tropical cyclone will pass within 180 n mi (shaded circle of Guam for the month of July. (Based on data from 1947-1973.)

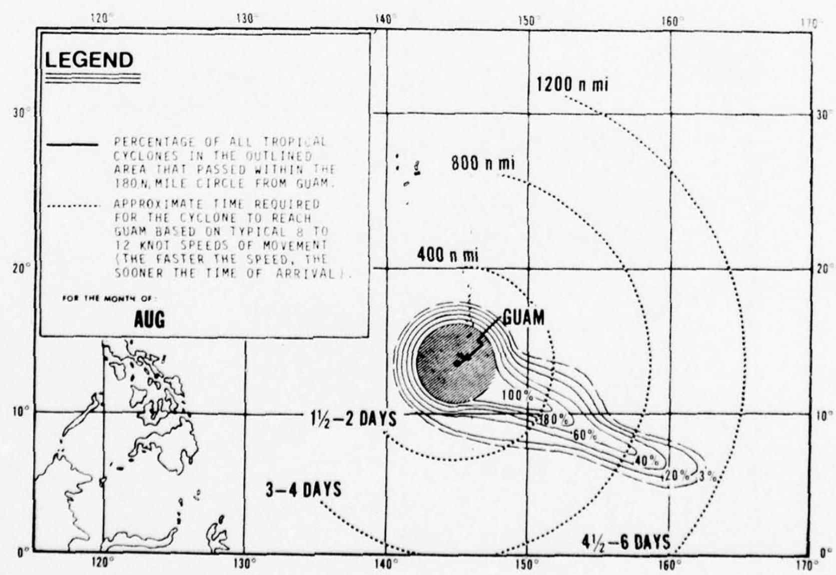

Figure II-9. Probability that a tropical cyclone will pass within 180 n mi (shaded circle) of Guam for the month of August. (Based on data from 1947-1973.)

GUAM
(APRA HARBOR)

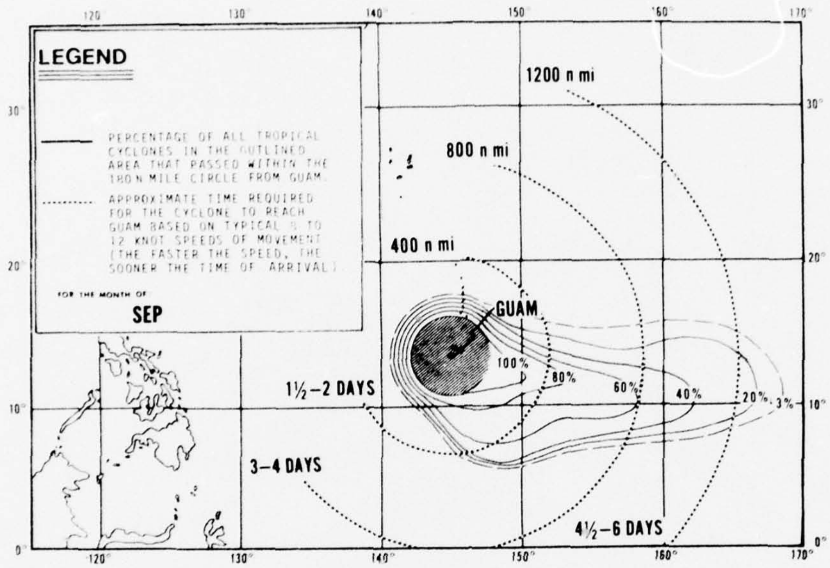

Figure II-10. Probability that a tropical cyclone will pass within 180 n mi (shaded circle) of Guam for the month of September. (Based on data from 1947-1973.)

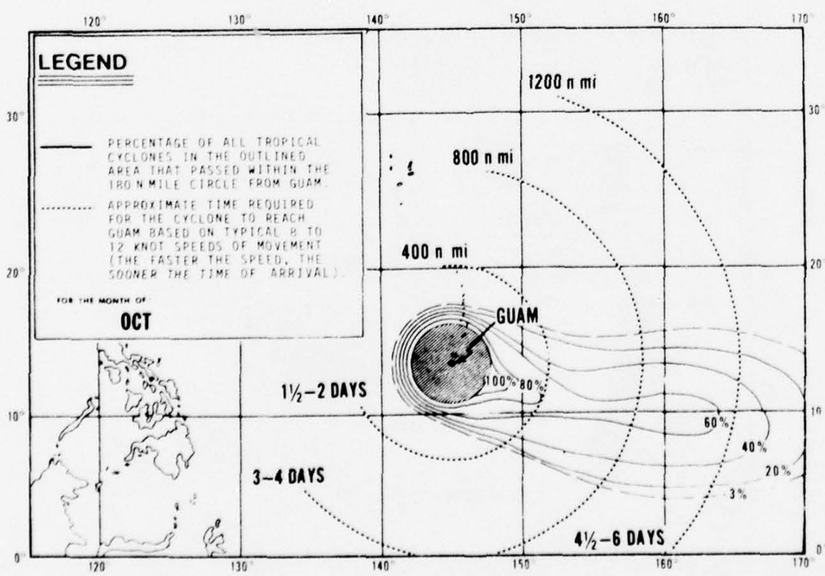

Figure II-11. Probability that a tropical cyclone will pass within 180 n mi (shaded circle) of Guam for the month of October. (Based on data from 1947-1973.)

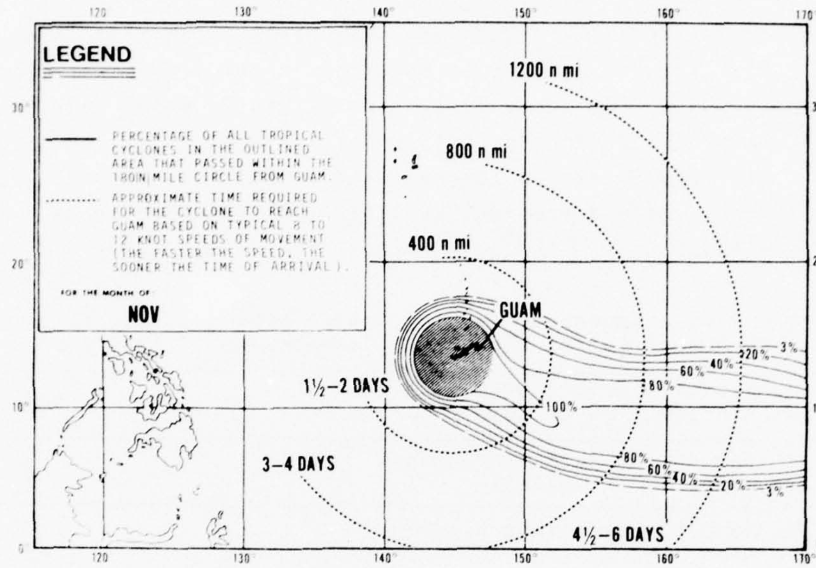

Figure II-12. Probability that a tropical cyclone will pass within 180 n mi (shaded circle) of Guam for the month of November. (Based on data from 1947-1973.)

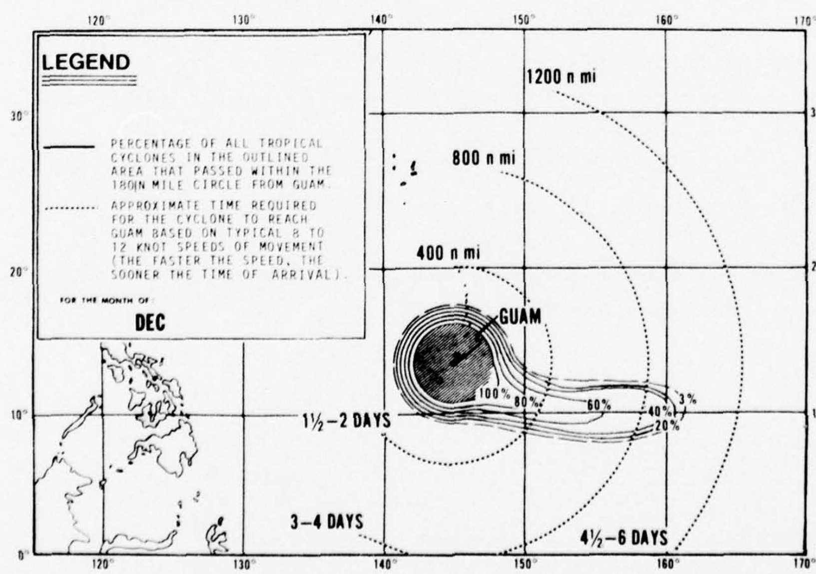

Figure II-13. Probability that a tropical cyclone will pass within 180 n mi (shaded circle) of Guam for the month of December. (Based on data from 1947-1973.)

GUAM
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In the 27 years 1947-1973 (considering the months June through December), an average of four tropical cyclones per year passed within 180 n mi of Guam (107 total). The largest number that occurred in any single year was seven (1958, 1965, and 1971). In Table II-1, the 107 storms which passed within 180 n mi are grouped according to their effect at Guam.[1] It can be seen that, of the total 107, only 34 storms (approximately 32%) resulted in winds of 22 kt or greater at Guam. Only 8 tropical cyclones (7%) resulted in gale-force winds or greater (≥34 kt).

Table II-1. Extent to which tropical cyclones affected Guam (NAS Agana) during the period June-December, 1947-1973.

Number of storms that passed within 180 n mi of Guam	107
Number of storms that resulted in winds ≥22 kt at Guam	34
Number of storms that resulted in winds ≥34 kt at Guam	8

Figure II-14 shows the tracks of the 8 gale associated storms. When the tracks in Figure II-14 are compared with the mean tracks in Appendix I-A, it becomes apparent that the majority that caused gale force winds have approached along a major threat axis that is oriented east-southeast from Guam. This axis is also shown in Figures II-7 to II-13 by the "percent threat" lines and in Figure II-4 by octant approach arrows.

Another significant feature indicated in Figure II-14 is that, of the eight storms that resulted in gale force winds during June-December 1947-1973, four occurred during the month of November. This is not to say that gale force winds may not occur during the other months (the fact is, WESTPAC typhoons can affect Guam during any month of the year) but climatology does indicate that the peak "threat" is apparent during November.

For a more detailed meteorological evaluation of Apra Harbor, Guam as a typhoon haven, see Brown and Brand, 1975.

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[1]Wind information is based on hourly wind observations from Naval Air Station, Agana, which is felt to be representative of the winds experienced in Apra Harbor.

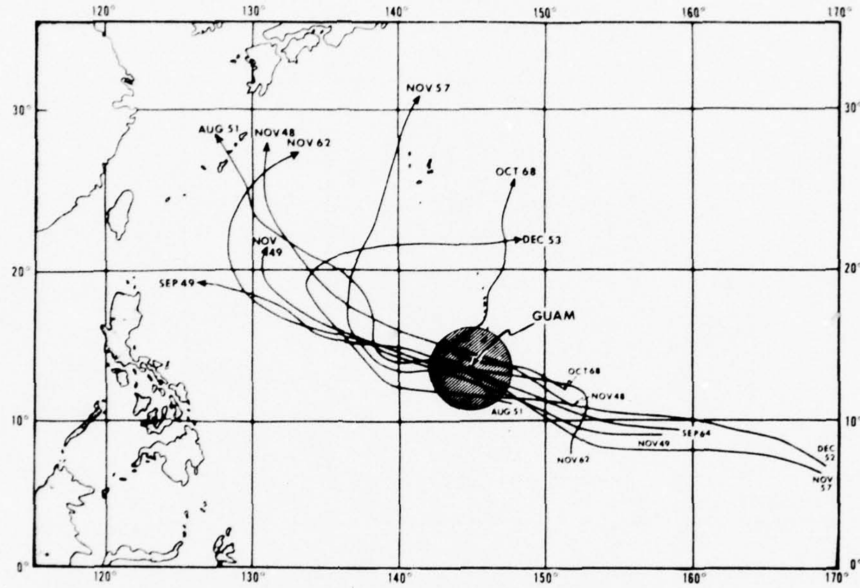

Figure II-14. Tracks of the tropical cyclones that resulted in gale force winds (≥34 kt) on Guam. (Based on hourly wind data recorded at NAS Agana from June-December, 1947-1973.)

2.3 EFFECTS OF TOPOGRAPHY

Of the 107 tropical cyclones that passed within 180 n mi of Guam in the June-December, 1947-1973 period, approximately 60% passed to the north and 40% passed to the south.

Figure II-15 shows the positions of the tropical cyclone centers (June-December, 1947-1973) when strong winds (≥22 kt) were first and last recorded at NAS Agana (based on hourly wind information). It is apparent that these strong winds do not occur until the storms reach approximately the longitude or just to the east of Guam. Notice that a number of storms have continued to give strong winds to Guam at distances of 200 n mi or more to the west. In general, strong winds can arise from storms passing 200 n mi to the south, and from storms passing 100 n mi to the north. There are more strong wind situations for storms passing to the south than to the north even though more storms had their CPA to the north. This is logical since storms passing south would place Guam in the high wind or dangerous semicircle. This bias is also evident in Figure II-16, which shows the tropical cyclone center positions when gale force (≥34 kt) winds were first and last recorded at NAS Agana. Notice that there was one gale occurrence at NAS Agana when the storm was centered over 200 n mi from Guam.

GUAM
(APRA HARBOR)

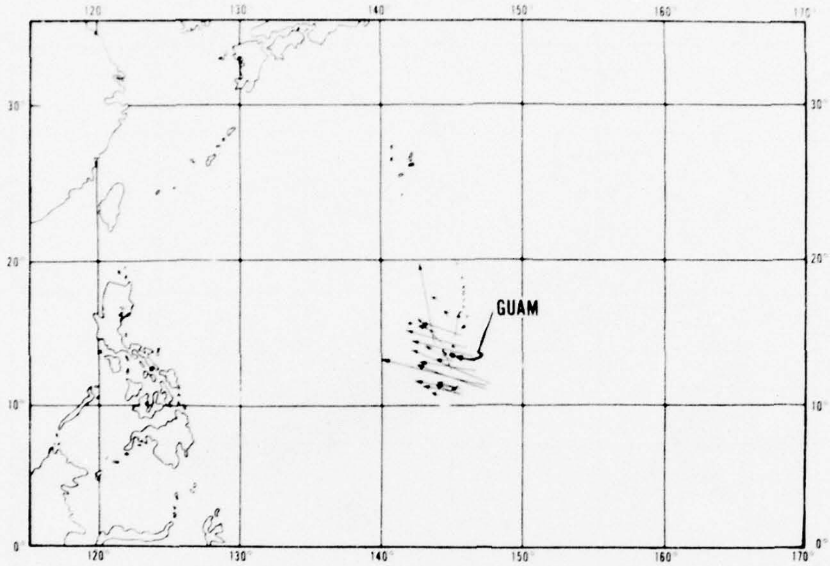

Figure II-15. Positions of tropical cyclone centers when $\geq$22 kt winds first and last occurred at Guam. (Based on NAS Agana data from June-December, 1947-1973.)

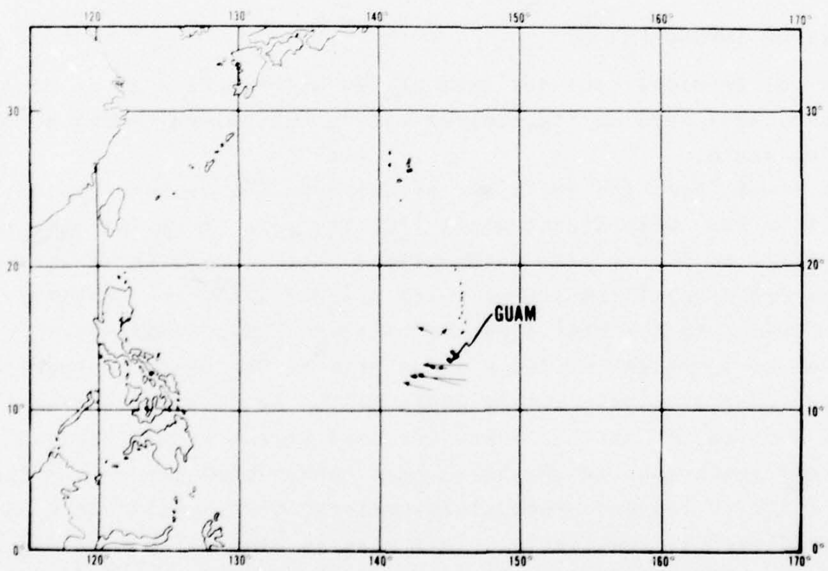

Figure II-16. Positions of tropical cyclone centers when $\geq$34 kt winds first and last occurred at Guam. (Based on NAS Agana data from June-December, 1947-1973.)

2.4 WAVE ACTION

Because of its extensive area and limited sheltering topographical features, Apra Harbor experiences considerable wave action during periods of tropical storm/typhoon passage.

Wave heights are primarily a function of wind speed, duration and fetch. Since Apra Harbor is open to the west, those storms that result in a westerly wind field over Guam expose the harbor entrance to severe wave action. In the outer harbor waves of 6-10 ft are "common" during storm passage and it is possible the maximum could exceed 20 ft under a westerly wind field of typhoon intensity. It is important to keep in mind that wave action may commence before local wind conditions reach particularly dangerous levels and may continue after the winds abate.

2.5 STORM SURGE

Storm surge can be defined as the difference in observed water level at a given location during storm and non-storm conditions. Storm surge is a major problem in Apra Harbor. Typhoon conditions have created surges 10-12 ft above mean lower low water level; while at the northern tip of Guam, surges in excess of 18 feet have been recorded. Obviously, these extreme changes in water level must be taken into account when planning for heavy weather situations.

2.6 THE DECISION TO EVADE OR REMAIN IN PORT

2.6.1 General

The criteria for setting local weather readiness conditions are set forth in COMMANDER IN CHIEF PACIFIC REPRESENTATIVE GUAM AND THE TRUST TERRITORY OF THE PACIFIC ISLANDS AND NAVAL FORCES MARIANAS JOINT INSTRUCTION 3141.1. In addition, this instruction requires specific action to be taken by various naval activities when weather conditions pose a threat to life or property. One such required action is that all Commanding Officers/Masters of Naval/Merchant ships present, attend a Heavy Weather Planning Meeting to discuss necessary action and the time required to complete this action. Since this meeting will cover evasion plans and heavy weather security it is imperative all personnel concerned attend.

2.6.2 Evasion Rationale

A most important aspect of any decision concerning heavy weather is an early appraisal of the threat posed by an individual tropical cyclone. Since the U.S. Navy's typhoon forecasting assets are readily available to units at Guam, a timely threat appraisal will be readily available and individual unit commanders will be able to take part in the evasion planning meetings called by COMNAVMARIANAS.

Historically, tropical cyclones have approached Guam from all directions and since most are in the developing stages, their movement as well as intensity and wind distribution, are difficult to forecast. This makes long range evasion planning very difficult. However, some rough guidelines that might be of use are presented in conjunction with Figure II-17.

I. An existing tropical cyclone moves into or significant development takes place in area A with forecast movement toward Guam:

   a. Review material condition of ship. A sortie may be desirable 2-4 days hence.

   b. Reconsider any maintenance that would render the ship incapable of getting underway within 48 hours.

II. Tropical cyclone moves into or significant development takes place in area B with forecast movement toward Guam:

   a. All units consider possible course of action if sortie should be ordered.

   b. Reconsider any maintenance that would render the ship incapable of getting underway within 24 hours.

III. Tropical cyclone enters area C moving toward Guam:

   a. Execute sortie.

2.6.3 Remaining In Port

Because of its lack of natural protection, Apra Harbor provides little or no haven qualities. Typhoon Karen (November 1962) gave Apra Harbor sustained winds of 150 kt! As a result, remaining in port is not the recommended course of action when typhoon conditions threaten. In the past, U. S. Navy ships have remained in port during typhoon conditions for various reasons.

Should a unit be required to remain in port, berths and/or nesting assignments will be made by Naval Station Guam/SOPA (ADMIN) Guam as specified in COMNAVMARIANAS Disaster Preparedness Plan 101. Individual unit commanders should be ready to rapidly respond to movement orders, because maneuvering after the onset of heavy weather (winds $\geq$20 kt) will be extremely hazardous. Remaining in port poses the problem of deciding on and then requesting the "best" possible mooring location. Such a location would be a function of ship type, expected sea state, wind speed/direction, and time available for the move. Based on limited past experience it is concluded that a general rule for winds up to 50 kt would be: "Obtain an inner harbor berth as close to the upwind shore as possible." It is recognized any ship subjected to high winds while moored will take some amount of beating but this rule should minimize the damage sustained.

Weather warnings concerning Guam and the trust territories of the Pacific islands are based on information gathered at Fleet Weather Central/ Joint Typhoon Warning Center, Guam (FWC/JTWC). All information and warnings are then broadcast to fleet units on appropriate Fleet Broadcast Channels. In addition, warnings are broadcast on Apra Harbor Control Frequency 2716 KHZ and Tug Control Frequency 3216 KHZ during typhoon/tropical storm conditions.

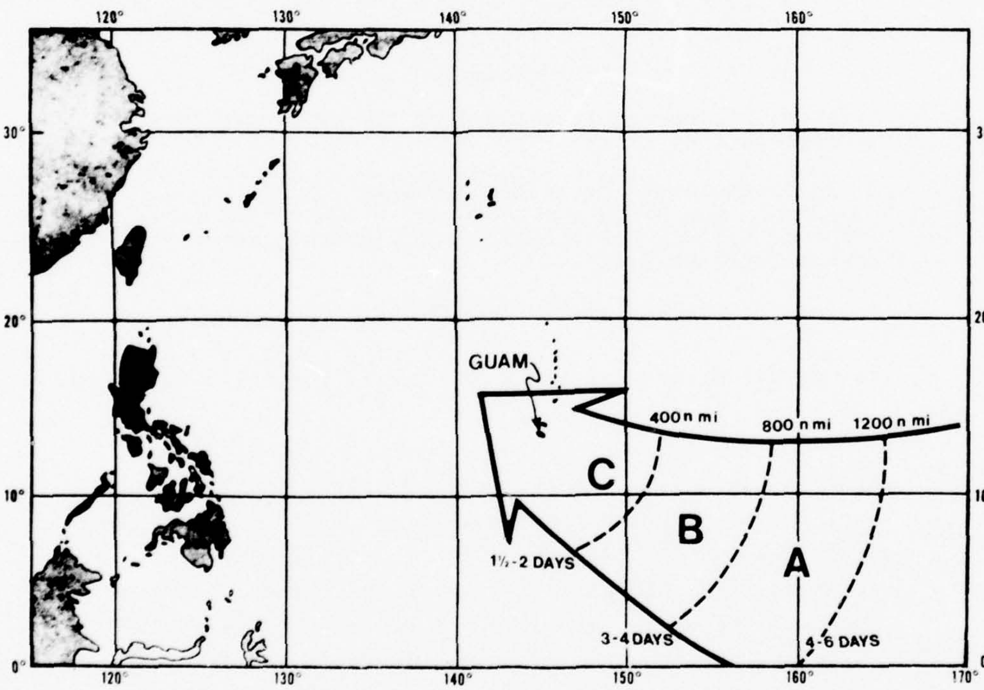

Figure II-17. Tropical cyclone threat axis for Guam. Distances and approach times are measured from Guam based on an 8-12 kt speed of movement.

2.6.4 Evasion At Sea

Evasion at sea is the preferred course of action when confronted with potential typhoon conditions at Guam. The commanding officer, with his experience and knowledge of his unit, will always make the final evasion decisions; however, the following evasion techniques are suggested for the more common "threat" situations.

I. Tropical cyclone approaching from the east or southeast and forecast to pass north or within 60 n mi south of Guam.

a. Evasion should be southwest. The units will be in the safe or navigable semicircle with following wind and sea.

II. Tropical cyclone approaching from the east of southeast and forecast to pass more than 60 n mi south of Guam:

a. Evasion should be northeast.

III. Tropical cyclone approaching from the south and forecast to pass east of Guam:

a. Evasion should be west-southwest.

IV. Tropical cyclone approaching from the south and forecast to pass west of Guam:

a. Evasion should be east-southeast.

In evading, whichever case presents itself, the following general comments should be noted:

1. Crossing ahead of an approaching typhoon, as recommended in I above, is not without hazard and must be accomplished well ahead of the typhoon. If, in attempting this track crossing, the ship is caught in the wave/swell pattern ahead of the storm, the speed of advance may be reduced to the point that the ship will be unable to maneuver clear of the storm (see paragraph 5 of Chapter I).

2. It is very possible during the peak typhoon season for rapid storm development to occur, resulting in multiple tropical cyclones co-existing in the western Pacific area. (This occurs approximately 50 days of each year.) This possibility would greatly complicate the evasion problem, and should be kept in mind as evasion plans are formulated and executed.

REFERENCES

Brand, S., J.W. Blelloch and D.C. Schertz, 1973: State of the Sea Around Tropical Cyclones in the Western North Pacific Ocean. ENVPREDRSCHFAC Technical Paper No. 5-73.

Brown, M.E. and S. Brand, 1975: An Evaluation of Apra Harbor, Guam as a Typhoon Haven. NAVENVPREDRSCHFAC Technical Paper No. 1975.

Burroughs, L.D. and S. Brand, 1972: Speed of Tropical Storms and Typhoons After Recurvature in the Western North Pacific Ocean. ENVPREDRSCHFAC Technical Paper No. 7-72.

Chin, P.C., 1972: Tropical Cyclone Climatology for the China Seas and Western North Pacific from 1884 to 1970. Royal Observatory Hong Kong, 207 pp.

U. S. Fleet Weather Central/Joint Typhoon Warning Center, Guam, 1971-73, Annual Typhoon Reports.

SECTION III - CONTENTS

III TAIWAN

1. GENERAL

Taiwan is a rugged island with well over half of its land area composed of mountainous terrain (see Figure III-1). The major mountain ranges are oriented north-south and run nearly the entire length of the island. These mountains pose a significant barrier to the circulation of tropical cyclones passing close to or crossing Taiwan.

Of the major cities on Taiwan, two - Chilung (Keelung) in the north and Kaohsiung in the south - are regularly used by contracted DOD vessels and the U.S. Navy for port calls.

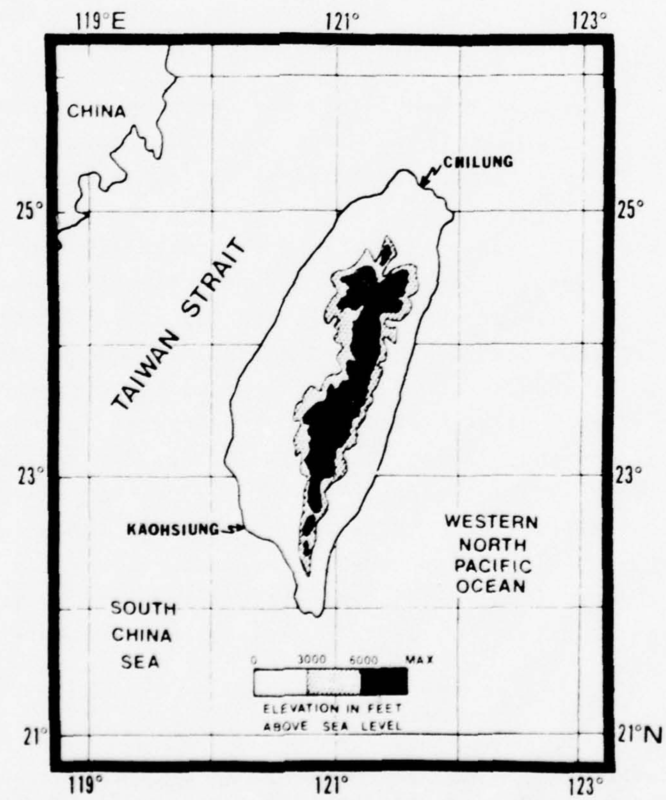

Figure III-1. Topographical map of Taiwan showing the locations of Kaohsiung and Chilung and approximate elevations above sea level.

2. KAOHSIUNG

SUMMARY

The conclusion reached by this study is in full agreement with the opinion held by Kaohsiung harbor authorities, both military and civil: "...Kaohsiung harbor is not to be considered a haven during typhoon conditions..." The key factor in reaching this conclusion was not weather conditions, but the threat posed by other ships in the confined harbor.

It is the recommendation of this study that all U.S. Navy ships capable take action to evade at sea when typhoon conditions threaten Kaohsiung, Taiwan.

2.1 LOCATION

The port city of Kaohsiung is located at the southern end of the west coast of Taiwan (see Figure III-1). The city is built on the western edge of a broad alluvial plain that extends east/west for 20 n mi. Directly east of Kaohsiung is the southern extremity of the central mountain ranges. These mountains play an important role in modifying the weather at Kaohsiung.

2.2 KAOHSIUNG HARBOR

Kaohsiung harbor is divided into two portions, an outer and an inner harbor (see Figure III-2). The outer harbor, used for temporary anchorage, is protected by breakwaters extending westward on the north and south. The inner harbor lies in a southeasterly direction between the coastal plain and a long, low, sandy peninsula. The inner harbor is approximately 9 n mi long with a maximum width of 750 yards.[1] There are two entrances: the main entrance at the northwest end, and a second entrance (presently under construction) approximately 5 n mi southeast of the main entrance. Date of completion of the second entrance is unknown at this time. The northern entrance is extremely narrow, the width being less than 150 yards at one point. Because of the congested nature of Kaohsiung harbor and its restricted entrance, pilotage is normally required for arrival and departure of all vessels. Berths normally assigned by port authorities to U.S. Navy ships are indicated in Figure III-2; point A for piers, and point B for buoys. The distance between buoys in Kaoshiung harbor is not standardized. Typhoons frequently shift the buoys short distances and no attempt is made to replace them in their original position.

[1]Kaohsiung harbor is presently undergoing an extensive construction program. For this reason any statements as to facilities and or dimensions are subject to change in the near future.

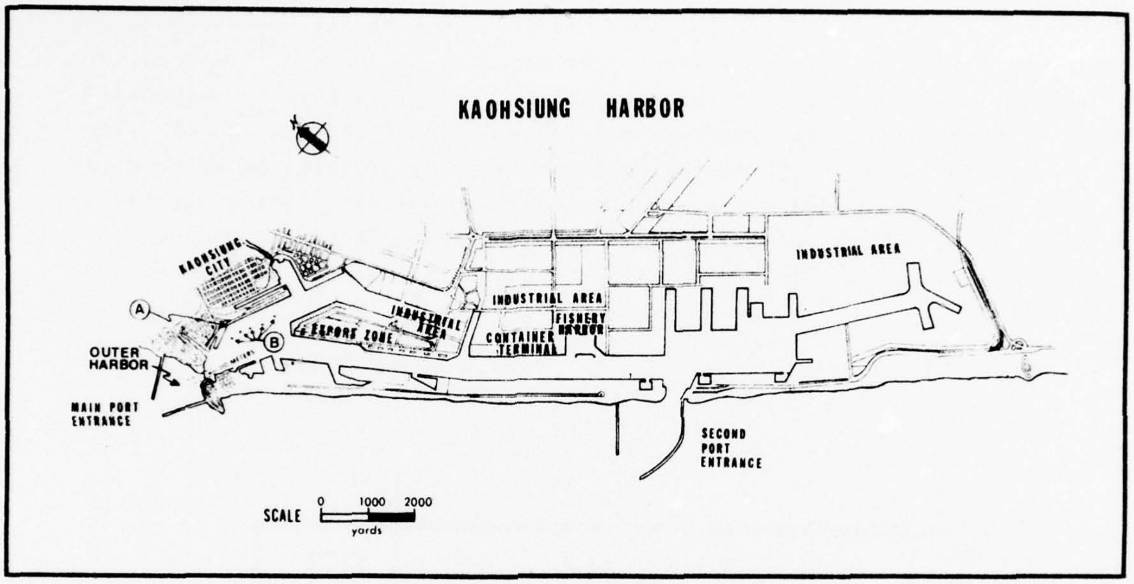

Figure III-2. Kaohsiung harbor showing the location of piers (A) and buoys (B) which are normally assigned to USN ships (after Kaohsiung Harbor Bureau, 1973).

2.3 PORT FACILITIES

The reader should refer to CINCPACFLT/COMSEVENTHFLT/MSTSFE Port Directory for detailed port facility information.

Located at the southern extreme of the harbor is a ship-scrapping facility (marked INDUSTRIAL AREA on Figure III-2), where ships scheduled for scrapping are beached and left unattended for extended periods. During the passage of tropical cyclones the combination of wind and wave action has refloated some of these derelicts which have then moved through the harbor, causing considerable damage to other vessels.

Another aspect of Kaohsiung harbor that must be taken into account is the civilian ships present in the harbor. During conversation with port authorities it was emphasized that the mooring equipment (lines, cables, etc.) of the civilian ships present is not always adequate for storm conditions. As a result, it is not uncommon for ships to break loose during high winds, causing damage to adjacent ships. It is obvious that in a crowded harbor such as Kaohsiung any ship out of control or drifting is an extreme danger.

It is primarily because of the above problems that port authorities consider Kaohsiung to be a poor haven during typhoon conditions.

2.4 TROPICAL CYCLONES AFFECTING KAOHSIUNG

2.4.1 Tropical Cyclone Climatology for Kaohsiung

Severe tropical cyclones can occur during any month of the year in the western Pacific area. However, the majority of those that pose a threat to Kaohsiung (any tropical cyclone approaching within 180 n mi is considered a "threat") occur during the months June-October. Figure III-3 gives the June-October monthly summary of threat situations by 5-day periods, based on data for the 24 years 1949-1972. Note that the maximum number of storms occur in the months July, August and September. Approximately 60% of the tropical cyclones passing within 180 n mi of Kaohsiung pass to the south; 40% pass to the north.

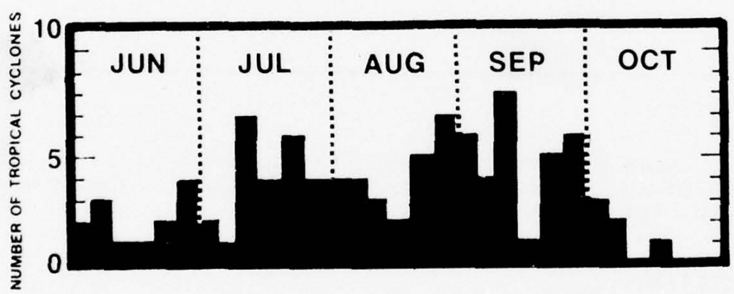

Figure III-3. Frequency distribution of the number of tropical cyclones that passed within 180 n mi of Kaohsiung. Subtotals are based on 5-day periods for tropical cyclones that occurred during 1949-1972.

In Figure III-4 these "threat" tropical cyclones are displayed according to the compass octant from which they approached Kaohsiung. The circled numbers indicate the total that approached from an individual octant. It is readily seen that a majority of storms approach from the southeast.

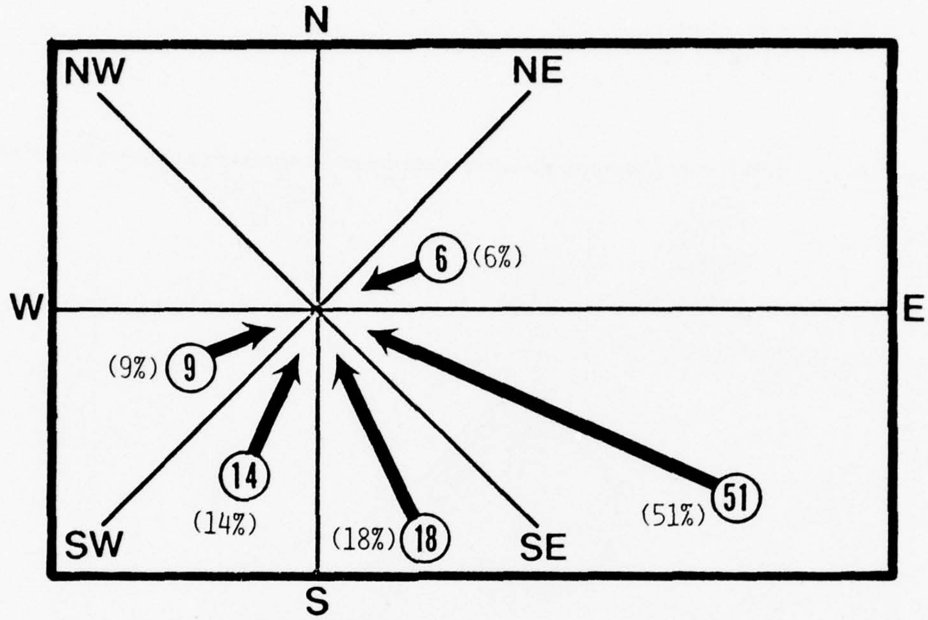

Figure III-4. Direction of approach to Kaohsiung of the tropical cyclones (1949-1972) that passed within 180 n mi of Kaohsiung. Circled numbers indicate the number that approached from each octant. The number in parentheses is the percentage of the sample (98) that approached from that octant.

Figures III-5 through III-9 present the percentage of tropical cyclones that have passed within 180 n mi of Kaohsiung (can be interpreted as a probability of threat) for the months of June-October. The dashed lines represent approximate approach times to Kaohsiung based on an approach speed of 8-12 kt. For example, in Figure III-5 a storm located at 130°E and 12°N has a 60% probability of passing within 180 n mi of Kaohsiung and, if its speed remains in the 8-12 kt range, it will reach Kaohsiung in approximately 3-4 days (the faster the speed of an individual storm the shorter the time required to reach Kaohsiung). The average speed of typhoons approaching Taiwan has been determined to be 10-11 kt (Brand and Blelloch, 1973).

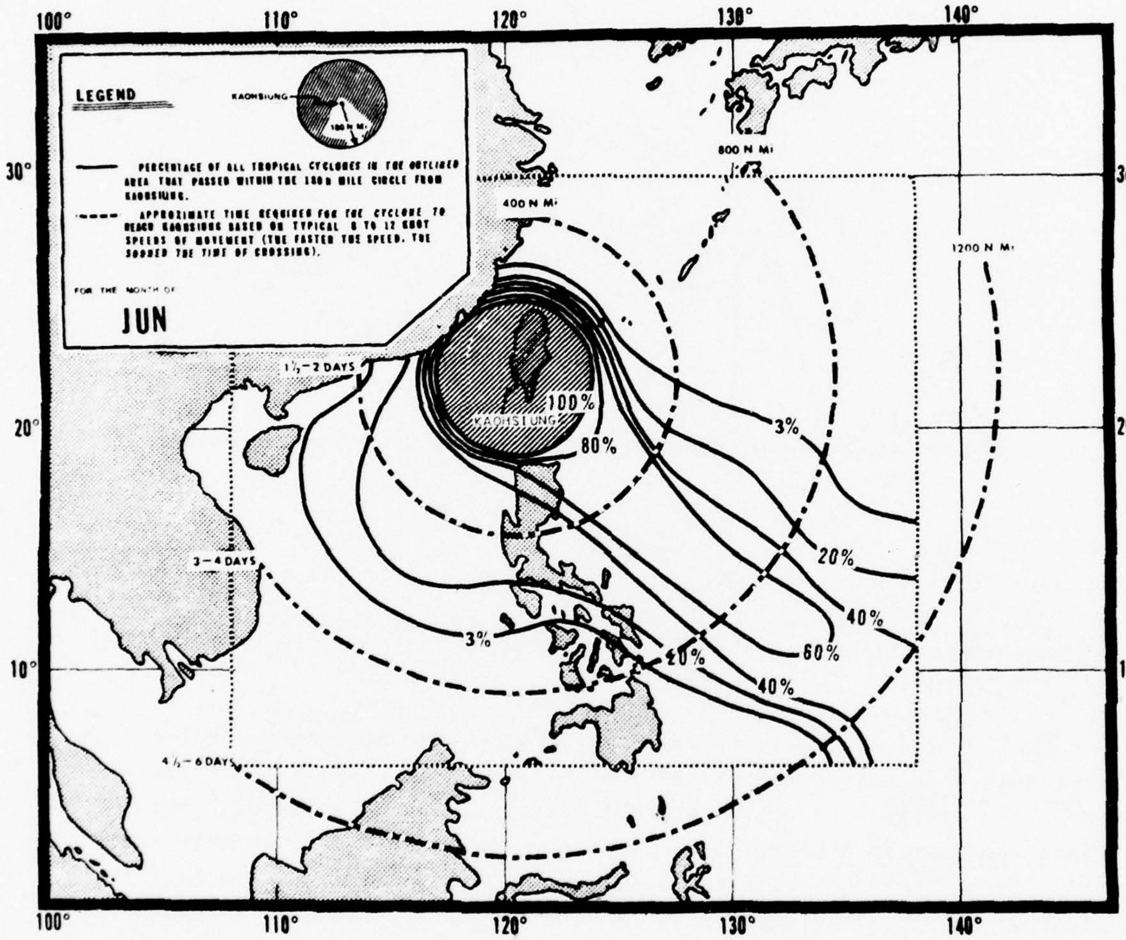

Figure III-5. Probability that a tropical cyclone will pass within 180 n mi of Kaohsiung for the month of June (based on data from 1884-1972).

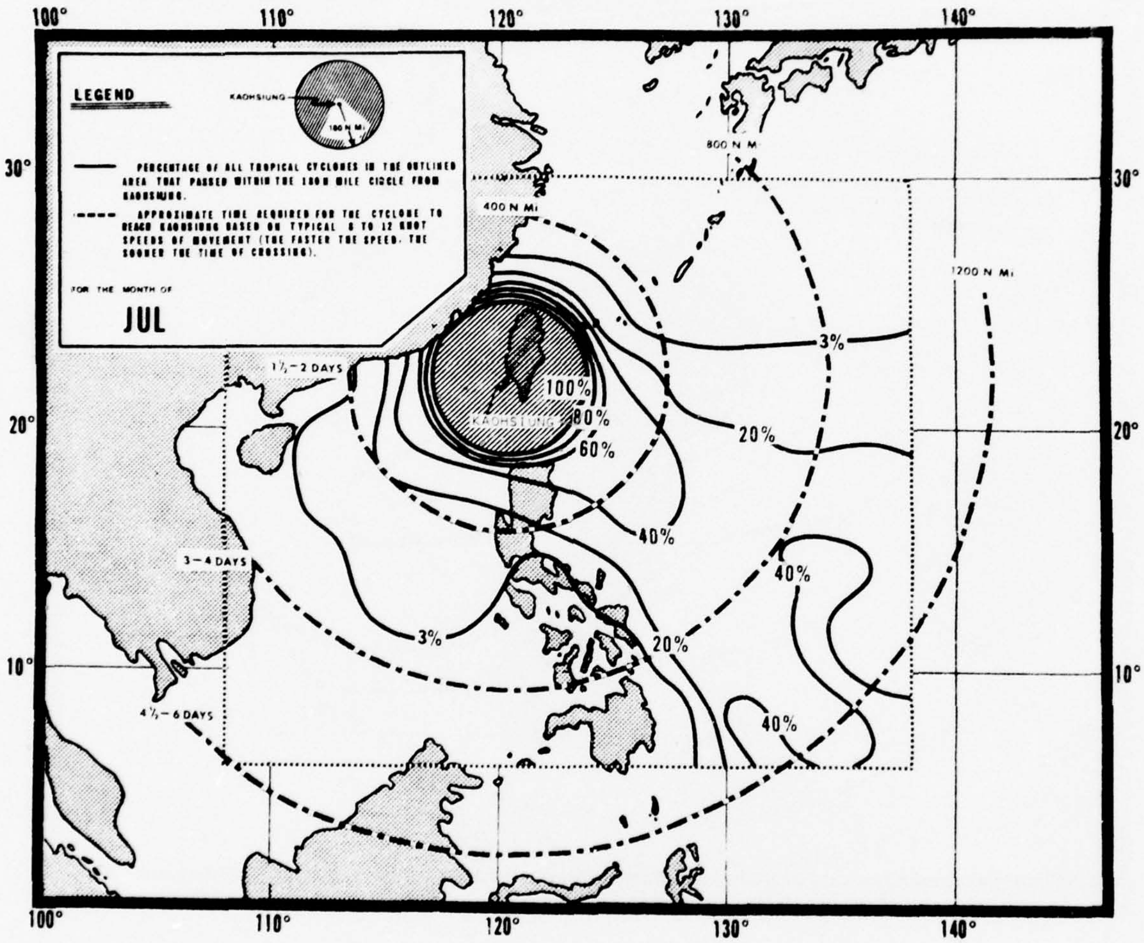

Figure III-6. Probability that a tropical cyclone will pass within 180 n mi of Kaohsiung for the month of July (based on data from 1884-1972).

KAOHSIUNG

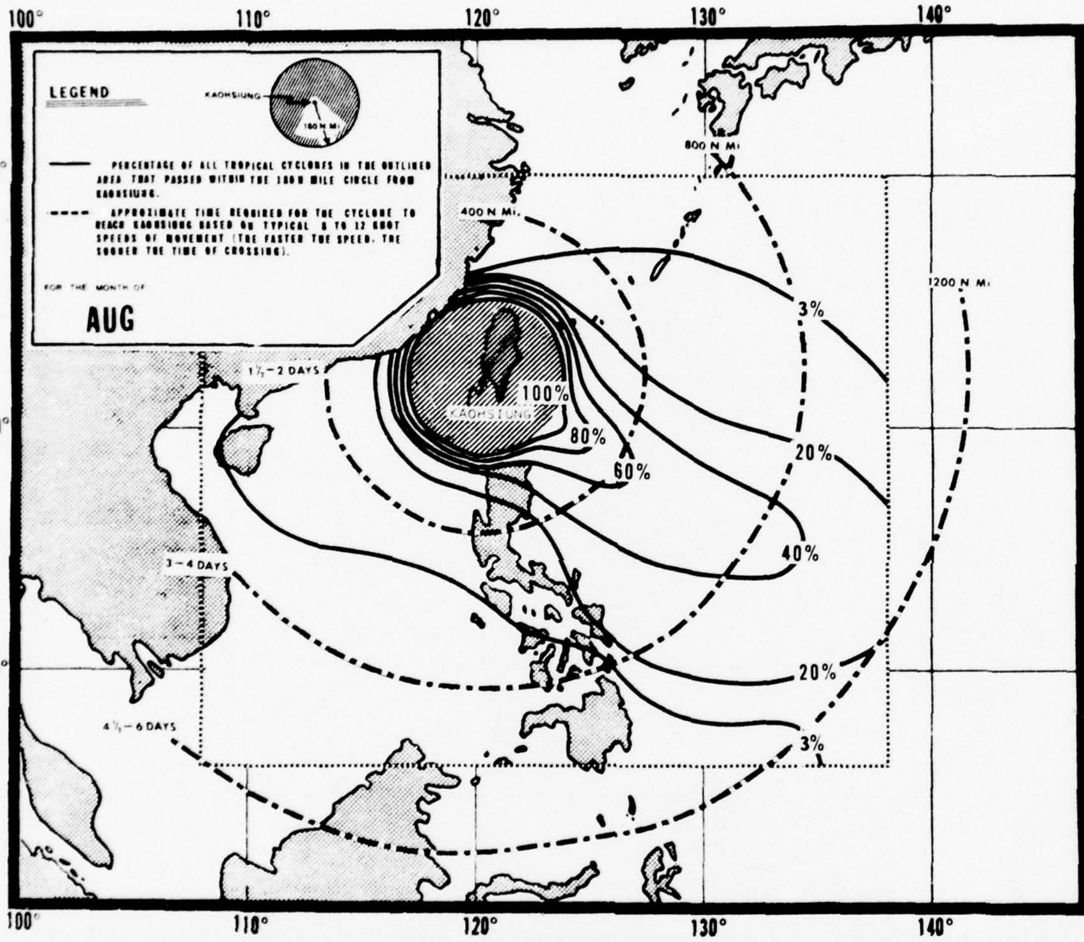

Figure III-7. Probability that a tropical cyclone will pass within 180 n mi of Kaohsiung for the month of August (based on data from 1884-1972).

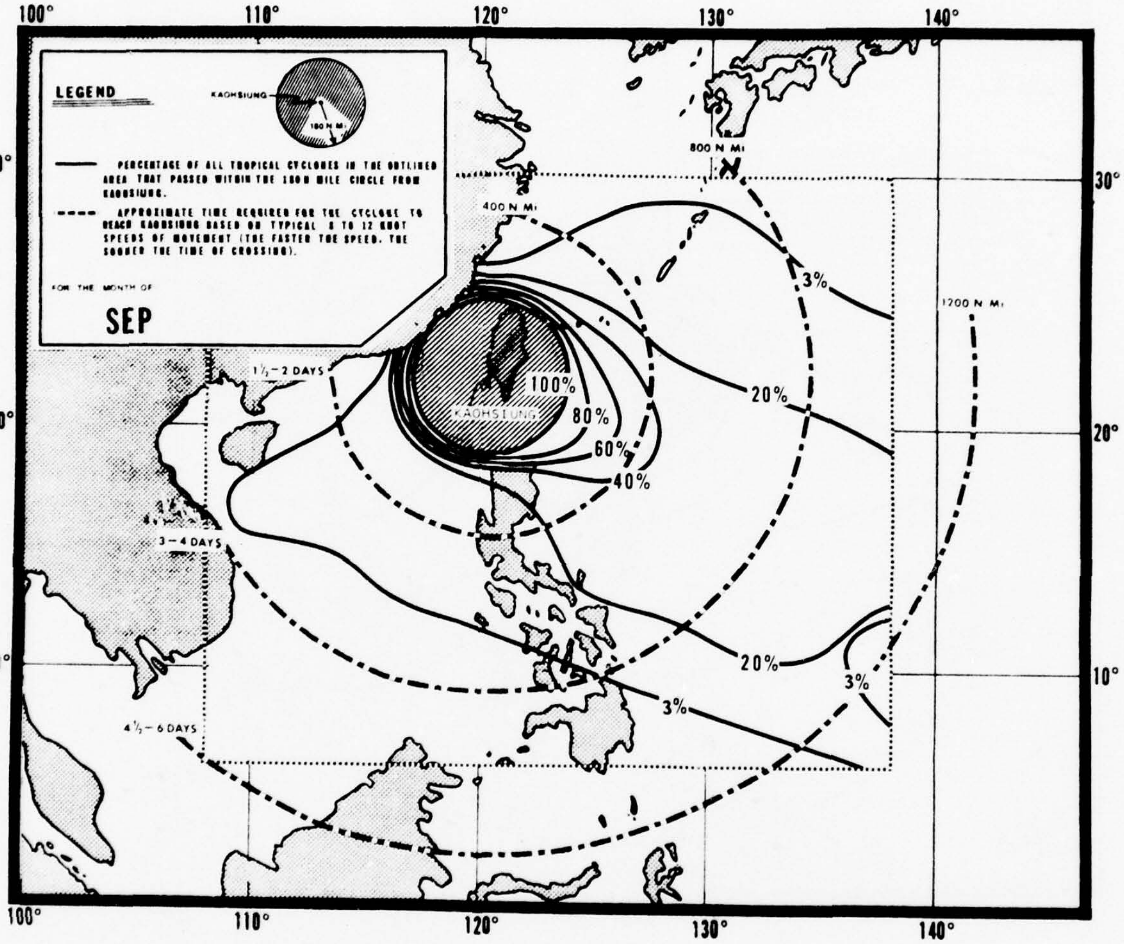

Figure III-8. Probability that a tropical cyclone will pass within 180 n mi of Kaohsiung for the month of September (based on data from 1884-1972).

KAOHSIUNG

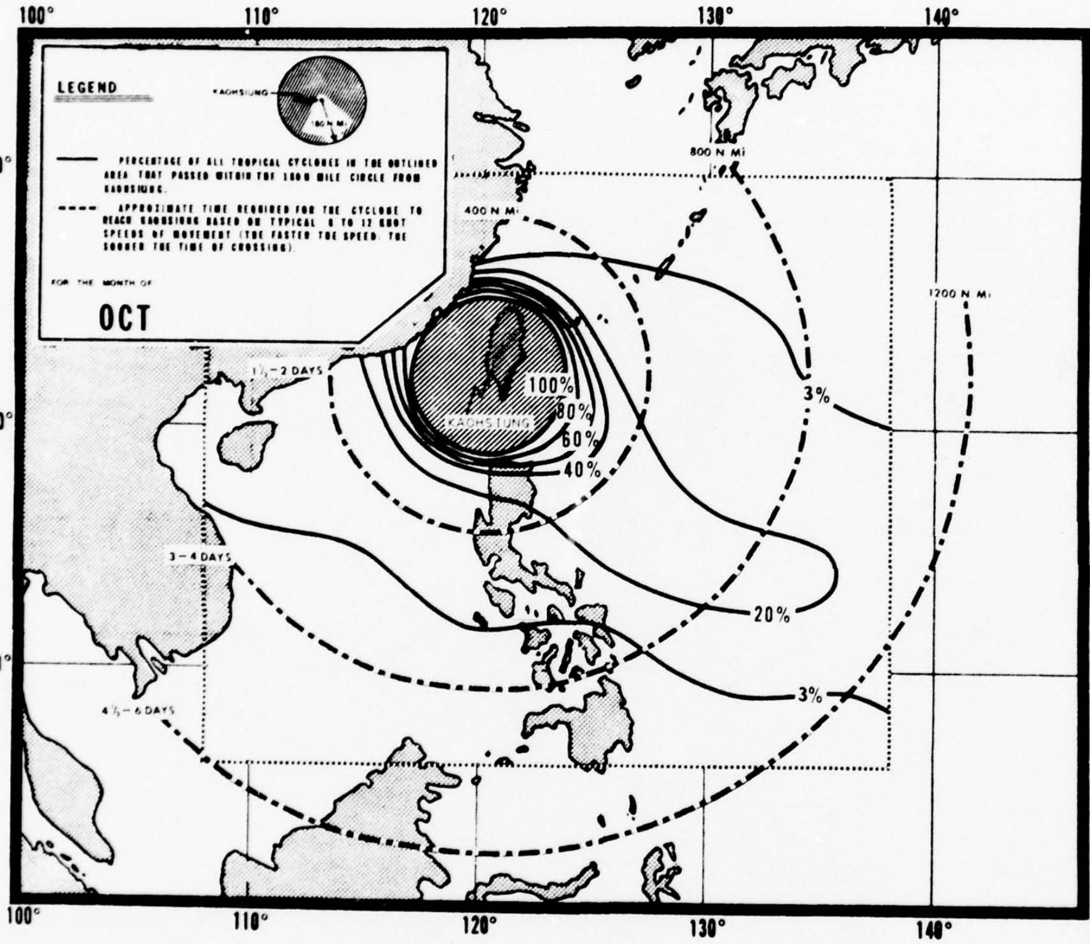

Figure III-9. Probability that a tropical cyclone will pass within 180 n mi of Kaohsiung for the month of October (based on data from 1884-1972).

In the 24 years 1949-1972 (considering the months June through October), an average of four tropical cyclones per year passed within 180 n mi of Kaohsiung (98 total). The largest number that occurred in any single year was six (1949 and 1965). In Table III-1 the 98 storms which passed within 180 n mi are grouped according to their effect at Kaohsiung. It can be seen that of the total 98, only 28 storms (approximately 30%) resulted in winds of 34 kt or greater at Kaohsiung. For a more detailed meteorological evaluation of Kaohsiung Harbor as a typhoon haven, see Brown (1974).

Table III-1. Extent to which tropical cyclones affected Kaohsiung during the period June-October, 1949-1972.

Number of storms that passed within 180 n mi of Kaohsiung	98
Number of storms that resulted in winds $\geq$ 22 kt at Kaohsiung	56
Number of storms that resulted in winds $\geq$ 34 kt at Kaohsiung	28

2.4.2 Effects of Topography

From analysis of the storm tracks it is apparent that those tropical cyclones that result in gales at Kaohsiung generally fall into two categories: those that cross Taiwan north of Kaohsiung, and those that pass to the south or southwest within 180 n mi of Kaohsiung. This difference is the key factor in determining to what extent an individual storm will affect Kaohsiung and how much time must be allowed for evasion. If the storm path is north or northeast of Kaohsiung across Taiwan, the storm will lose much of its intensity through interaction with the land prior to affecting the Kaohsiung area. For this reason, even fully developed typhoons passing north of Kaohsiung have at times little effect on the harbor. An example of this was Typhoon Agnes (September, 1971) which crossed Taiwan 50 n mi north of Kaohsiung. When Agnes approached the east coast of Taiwan on 18 September maximum winds were reported as 70 kt; within 12 hours, as the storm crossed the island, the maximum wind had decreased by 42% to 40 kt. Throughout this period the wind at Kaohsiung did not exceed 24 kt.

In the case of a storm passing south or southwest of Kaohsiung, the path of the storm is entirely over water and the storm reaches its closest point of approach to Kaohsiung at or near full intensity.[2] This type of

[2] Some storms may have crossed the Philippines but have had a transit over water of sufficient length to regain most of their pre-Philippine intensity.

approach also places Kaohsiung in the "dangerous" or right semicircle of the storm subjecting the harbor to the highest wind velocities present in the particular storm. An example of this case was Typhoon Viola (July 1969). Viola's eye passed well south of Kaohsiung, the closest point of approach being more than 120 n mi to the south, yet the wind at Kaohsiung reached 47 kt.

In reviewing available wind records for 24 years (1949-1972), it was noted no observation exceeded 65 kt. While this is a very substantial velocity, it is somewhat below what might be expected in view of the unprotected southern approaches to Kaohsiung harbor and its history of frequent storm occurrence. The mountain ranges east of Kaohsiung (Figure III-1) are one explanation for this lack of high winds. It is thought that the mountains disrupt the circulation of storms approaching from most quadrants, thereby limiting surface wind speeds in the Kaohsiung area.

This sheltering effect is also evident in Figures III-10 and III-11. Figure III-10 shows the position of the tropical cyclone centers when the wind speed first and last exceeded 22 kt at Kaohsiung. Generally, the storm must be within 120 n mi of Kaohsiung before the wind picks up. Figure III-11 shows positions of tropical cyclone centers when wind speeds first and last exceeded 34 kt at Kaohsiung. Notice those storms passing to the north effect Kaohsiung for a shorter period than those passing to the south.

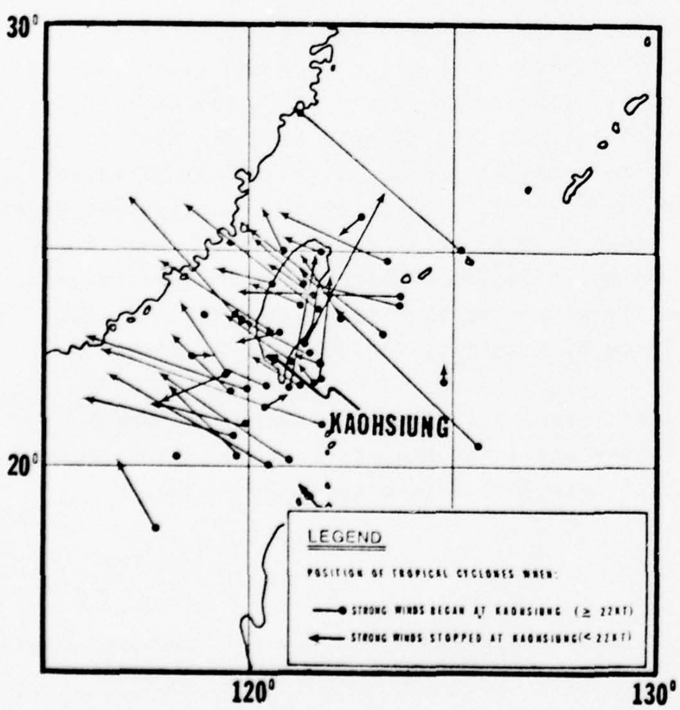

Figure III-10. Positions of tropical cyclone centers when winds of 22 kt or more were first and last observed at Kaohsiung (based on data from the years 1949-1972).

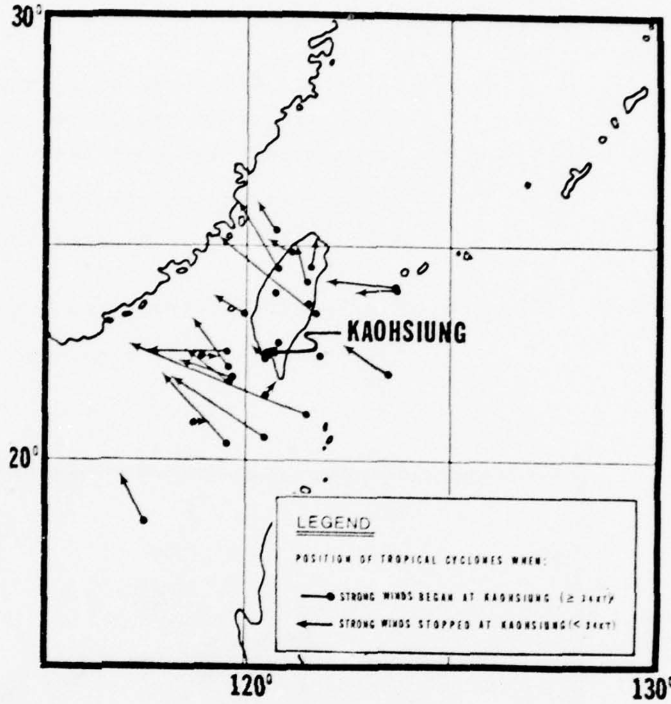

Figure III-11. Positions of tropical cyclone centers when winds of 34 kt or more were first and last observed at Kaohsiung (based on data from the years 1949-1972).

2.5 THE DECISION TO EVADE OR REMAIN IN PORT

2.5.1 General

A most important aspect of any decision concerning heavy weather is an early appraisal of the threat posed by an individual tropical cyclone. The preparation should begin when enough time remains to allow flexibility in the evasion plan. To facilitate early action, the following time table (in conjunction with Figure III-12) has been set up.

I. An existing tropical cyclone moves into or development takes place in area A with forecast movement toward Kaohsiung:

   a. Review material condition of ship. A sortie may be desirable 2-4 days hence.

   b. Reconsider any maintenance that would render the ship incapable of getting underway within 48 hours.

II. Tropical cyclone enters area B moving toward Kaohsiung:

a. All ships begin planning course of action to be taken if sortie should be ordered. A sortie may be desirable 1-2 days hence.

b. Reconsider any maintenance that would render the ship incapable of getting underway within 24 hours.

III. Tropical cyclone enters area C moving toward Kaohsiung:

a. Execute sortie plans made in previous steps.

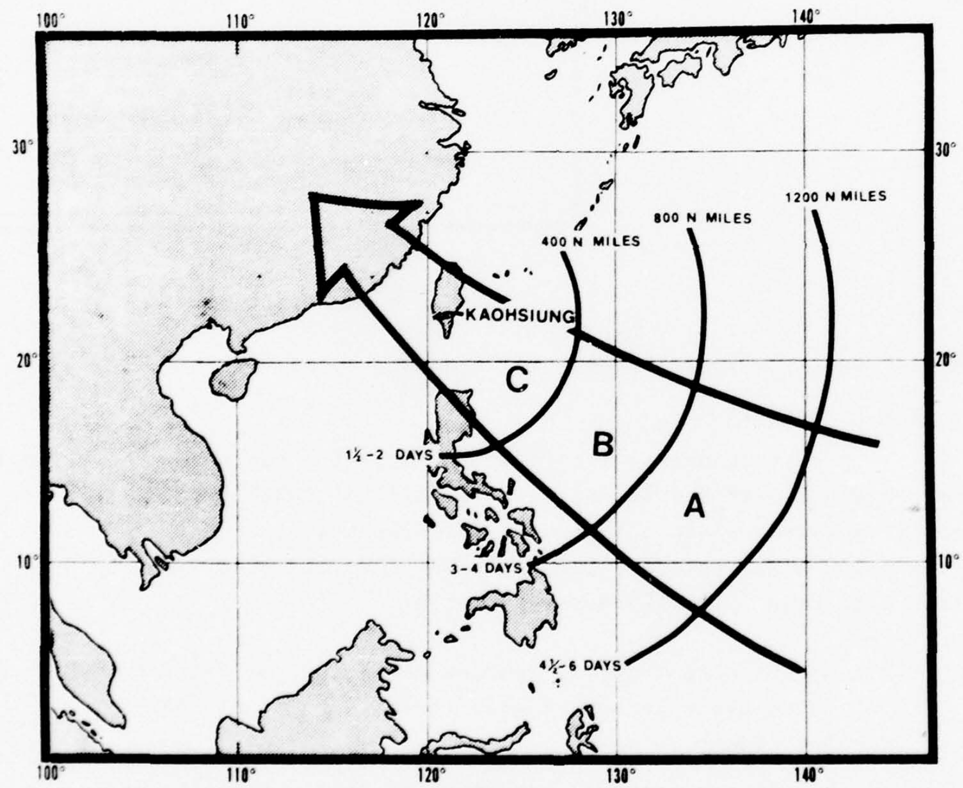

Figure III-12. Tropical cyclone threat axis for Kaohsiung. Distance and approach times are measured from Kaohsiung based on 8-12 kt speed of movement.

Due to the confined nature of the harbor and the difficulty experienced in maneuvering in strong winds, the ship should be ready to get underway before the storm center approaches within 400 n mi. If this general rule is followed, more than enough time will be available to clear Kaohsiung harbor before the wind reaches 20 kt. If the storm approaches within 350 n mi before the sortie is complete, the winds and seas outside the harbor will have reached a state where they could lower the ship's speed of advance. This could greatly complicate the evasion plan.[3] The criteria for setting local heavy weather readiness conditions are discussed in SOPA (ADMIN) KAOHSIUNG INST 5000.1 series.

2.5.2 Remaining in Port

Remaining in port is not the recommended course of action when typhoon conditions threaten Kaohsiung. If for any reason the ship must remain in port, the following points should be considered:

(1) Securing to pier or buoy must be accomplished before the wind reaches 20 kt in order to avoid undue difficulty.

(2) There are no sheltered berths in Kaohsiung harbor.

(3) Once the heavy weather begins, the confined harbor with its narrow entrances preclude getting underway until weather conditions abate.

2.5.3 Evasion at Sea

Evasion at sea is the preferred course of action when confronted with potential typhoon conditions at Kaohsiung. The commanding officer with his experience and knowledge of his particular unit will always make the final evasion decisions. However, the following evasion techniques are suggested for the more common threat situations:

---

[3]See section 5 of Chapter 1 for discussion and examples of the extent to which sea state and wind speed reduce speed of advance.

I. Tropical cyclone approaching from the southeast and forecast to pass north or east of Kaohsiung.

Evasion should be south into the South China Sea. The units will be in the safe or navigable semicircle with following wind and sea.

II. Tropical cyclone approaching from the southeast and forecast to pass south of Kaohsiung:

Evasion should be south into the South China Sea. In this case the evasion route crosses ahead of the typhoon (see comment (2) below).

III. Tropical cyclone approaching from the South China Sea:

Evasion should be southeast into the Pacific Ocean (see comment (3) below).

In evading, whichever case presents itself, three general comments should be noted:

(1) Evasion through the Taiwan Strait is not recommended due to the violent sea state and strong winds likely to be encountered.

(2) Crossing ahead of an approaching typhoon is not without hazard, and must be accomplished well ahead of the typhoon. If, in attempting this track crossing the ship is caught in the wave/swell pattern ahead of the storm, the speed of advance may be reduced to the point that the ship will be unable to maneuver clear of the storm (see section 5 of Chapter I).

(3) It is very possible during the peak typhoon season for rapid storm development to occur, resulting in two or more tropical cyclones co-existing in the western Pacific area. This possibility would greatly complicate the evasion problem, and should be kept in mind as evasion plans are formulated and executed.

2.5.4 Wave Action

Kaohsiung inner harbor experiences only minor wave action during typhoon passage due to the confined nature of the harbor with its small area. However, the currents and sea state outside Kaohsiung harbor have been a significant threat to ships attempting to enter or leave the harbor prior to the onset of typhoon conditions. One explanation for this problem is shoaling. The water depth decreases rapidly from 6000 ft to less than 200 ft in the area to the southwest of Taiwan. It is this rapid shoaling which causes the high sea states observed outside Kaohsiung harbor prior to and during typhoon passage. This expected wave action should be considered if a sortie becomes necessary.

2.5.5 Storm Surge

Storm surge can be defined as the difference in observed water level at a given location during the storm and non-storm conditions.

There are no records of storm surge occurring in Kaohsiung harbor, and conversations with the Harbor Bureau Engineering Staff indicate that, if it does occur, it is very minor and hence poses no serious problem for shipping inside the harbor boundaries.

3. CHILUNG (KEELUNG)

SUMMARY

The conclusion reached in this study is that Chilung harbor is a poor haven during typhoon conditions. The key factors in reaching this conclusion were:

1. Sea states in the outer harbor can exceed 20 ft during typhoon conditions.

2. The threat of other vessels adrift in the confined harbor.

3. The lack of sheltered berths.

It is the recommendation of this study that all U.S. Navy ships capable take action to evade at sea when typhoon conditions threaten Chilung, Taiwan.

3.1 LOCATION

The port city of Chilung, located at the northern tip of Taiwan (see Figure III-1), is the major seaport for the capitol city of Taipei. Chilung is situated on a deep, natural bay surrounded on three sides by mountains. It will be seen that these mountains significantly modify the wind field which affects Chilung.

3.2 CHILUNG HARBOR

Chilung harbor is divided into two portions: An outer harbor and an inner harbor (see Figure III-13). The outer harbor, which is entered from the north, is partially protected from the open ocean by two stone breakwaters. There are many pier/quay wall berths and adequate anchorages available in the outer harbor. Chilung's inner harbor is a narrow and confined area extending southwest from the outer harbor. The maximum width of the inner harbor is only 400 yards; in addition, ships moored on either side of the channel further reduce the space available for maneuvering.

The single entrance to Chilung harbor is a narrow (300 yard) gap in the breakwaters. The entrance is subject to continuous currents and pilotage is recommended when entering or leaving Chilung.

U.S. Navy ships are normally assigned to anchorages in the outer harbor or to one of the inner harbor buoys.

3.3 PORT FACILITIES

The reader should refer to CINCPACFLT/COMSEVENTHFLT/MSTSFE Port Directory for detailed port facility information.

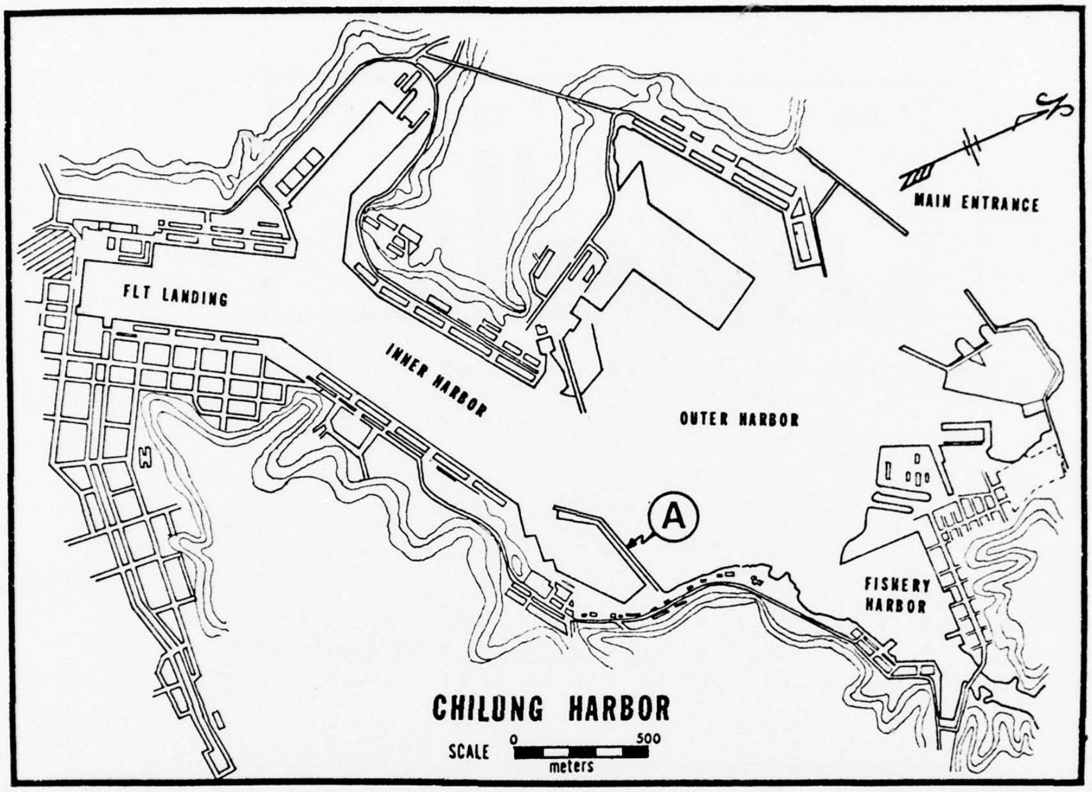

Figure III-13. Chilung Harbor.

An aspect of Chilung harbor that must be taken into account is the civilian ships present in the harbor. During conversation with port authorities it was emphasized that the mooring equipment (lines, cables, etc.) of the civilian ships present is not always adequate for storm conditions. As a result, it is not uncommon for ships to break loose during high winds, and cause damage to adjacent ships.

3.4 TROPICAL CYCLONES AFFECTING CHILUNG

3.4.1 Tropical Cyclone Climatology for Chilung

Severe tropical cyclones can occur during any month of the year; however, the majority of those that pose a potential threat to Chilung (any tropical cyclone approaching within 180 n mi is considered a "threat") occur during the period June through early October. Figure III-14 gives the monthly summary, by 5-day periods, based on data for the 24 years 1949-1972. Note that the threat level is fairly constant for the months June through September. Approximately 70% of the tropical cyclones that pass within 180 n mi of Chilung pass to the south, 30% to the north.

CHILUNG (KEELUNG)

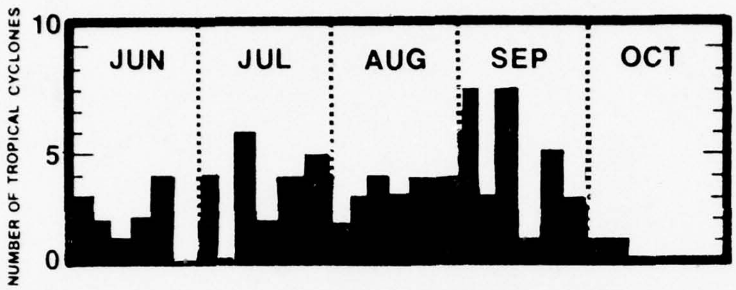

Figure III-14. Frequency distribution of the number of tropical cyclones that passed within 180 n mi of Chilung. Subtotals are based on 5-day periods for tropical cyclones that occurred during 1949-1972.

In Figure III-15 the threat storms are displayed as a function of the compass octant from which they approached Chilung. The circled numbers indicate the number that approached from an individual octant, while the numbers in parentheses indicate the percent of the total that approached from that octant. Note that the majority approach from the south-southeast.

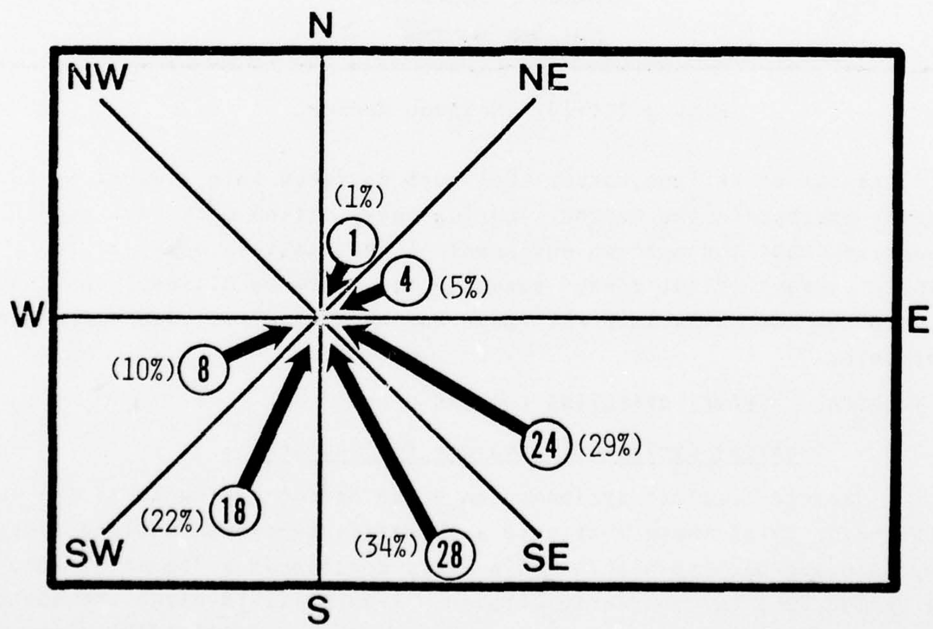

Figure III-15. Direction of approach to Chilung of the tropical cyclones (1949-1972) that passed within 180 n mi of Chilung. Circled numbers indicate the number that approached from each octant. The numbers in parentheses is the percentage of the total sample (83) that approached from that octant.

Figures III-16 through III-20 present the percentage of tropical cyclones that have passed within 180 n mi of Chilung (can be interpreted as probability of threat) for the months June-October. The dashed lines represent approximate approach times to Chilung based on an approach speed of 8-12 kt. For example, in Figure III-16 a storm located at 130°E and 15°N has about a 40% probability of passing within 180 n mi of Chilung and, if its speed remains in the 8-12 kt range it will reach Chilung in approximately 3-4 days (the faster the speed of an individual storm the shorter the time required to reach Chilung). The average speed of typhoons approaching Taiwan has been determined to be 10-11 kt (Brand and Blelloch, 1973).

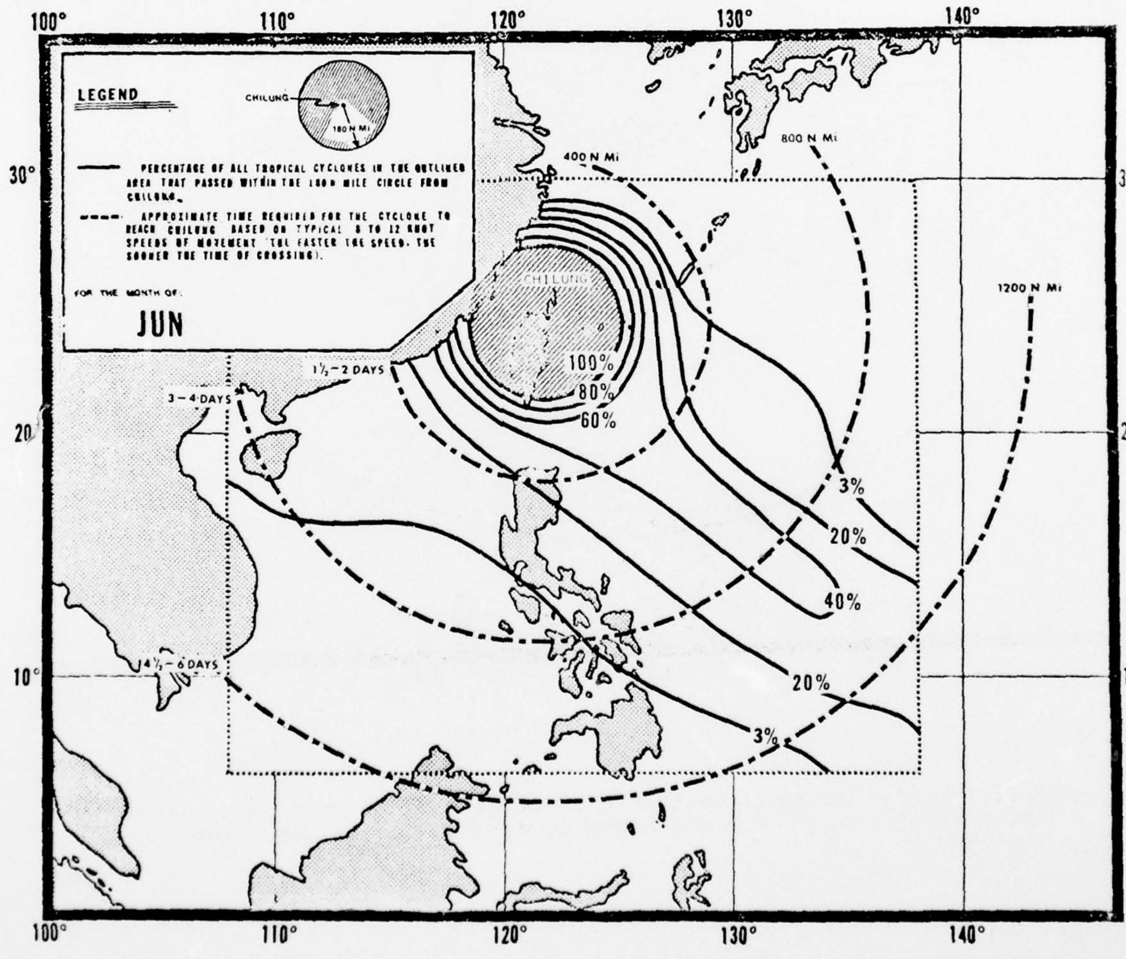

Figure III-16. Probability that a tropical cyclone will pass within 180 n mi of Chilung for the month of June (based on data from 1884-1972).

CHILUNG
(KEELUNG)

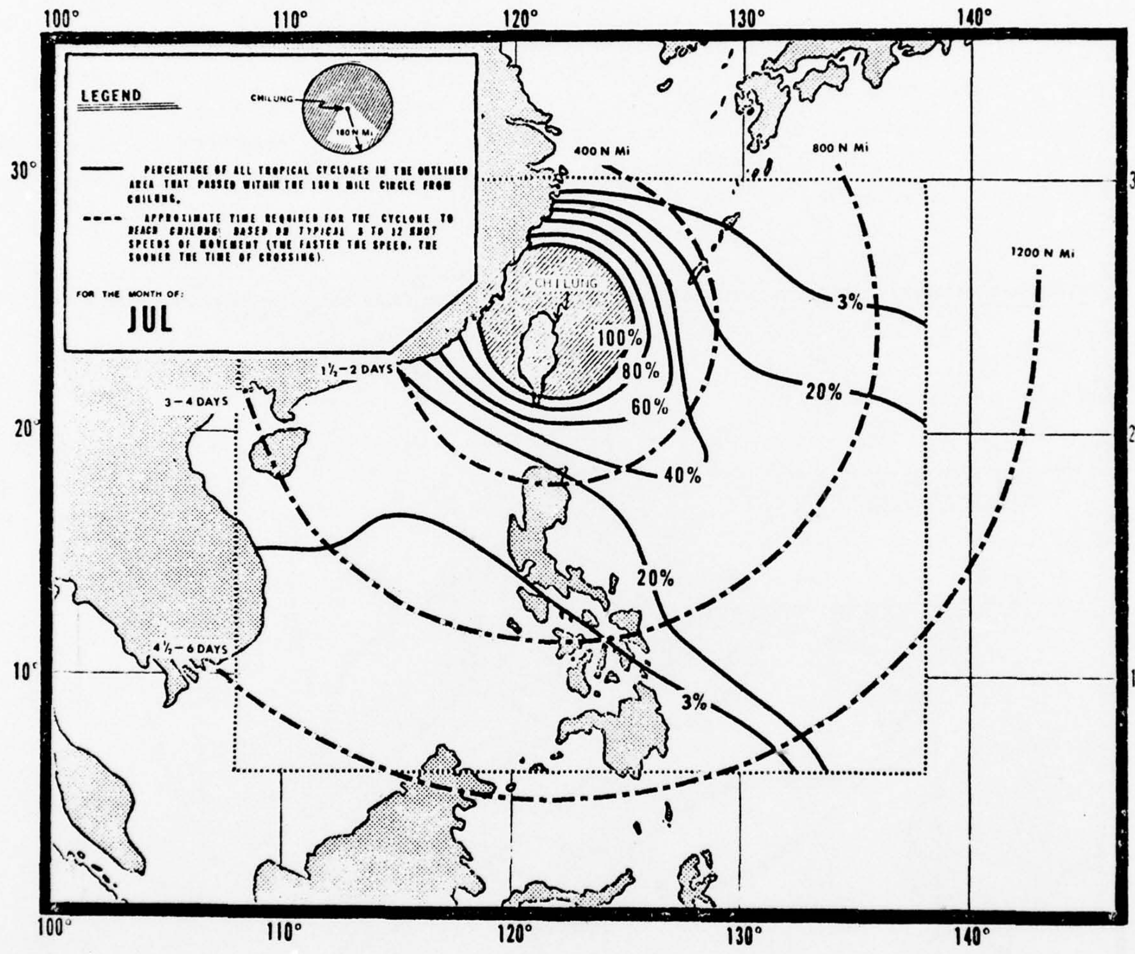

Figure III-17. Probability that a tropical cyclone will pass within 180 n mi of Chilung for the month of July (based on data from 1884-1972).

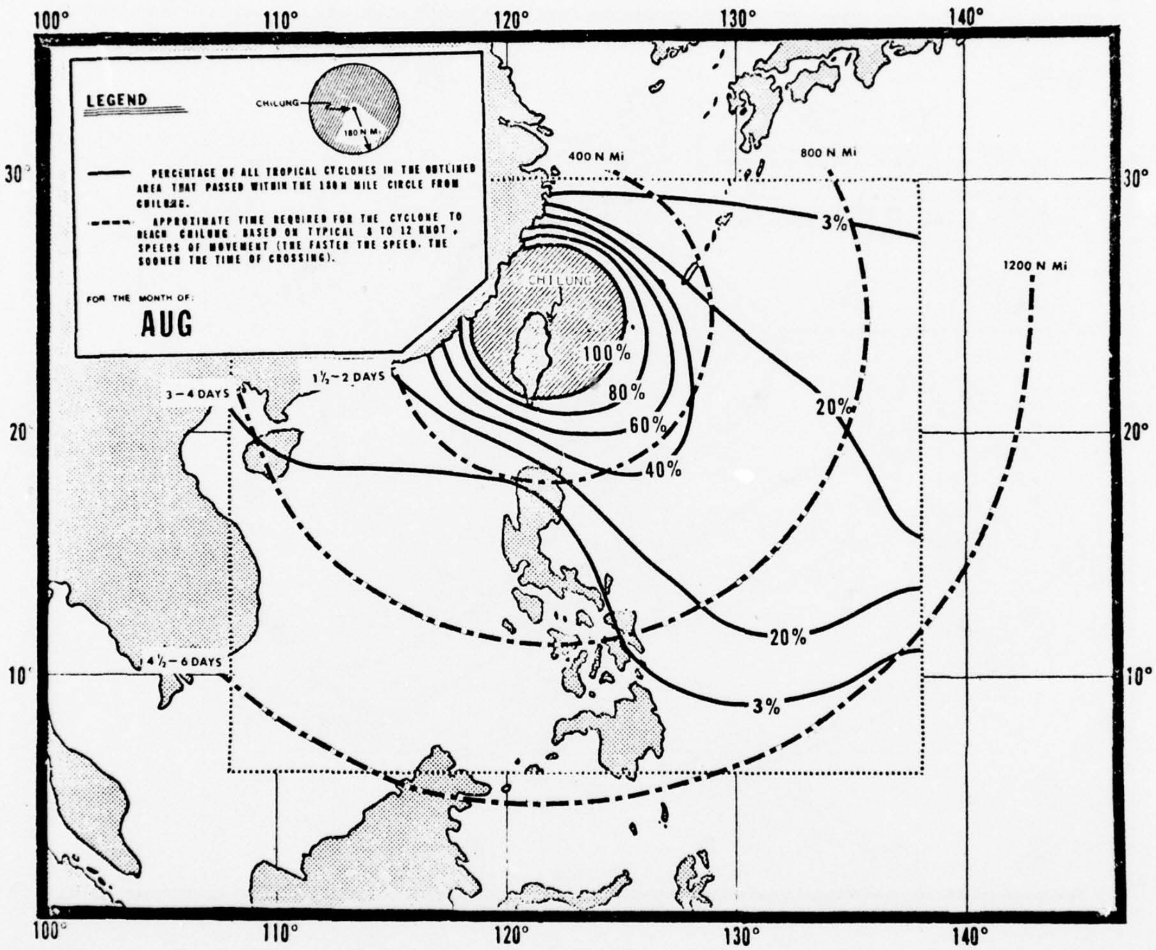

Figure III-18. Probability that a tropical cyclone will pass within 180 n mi of Chilung for the month of August (based on data from 1884-1972).

CHILUNG
(KEELUNG)

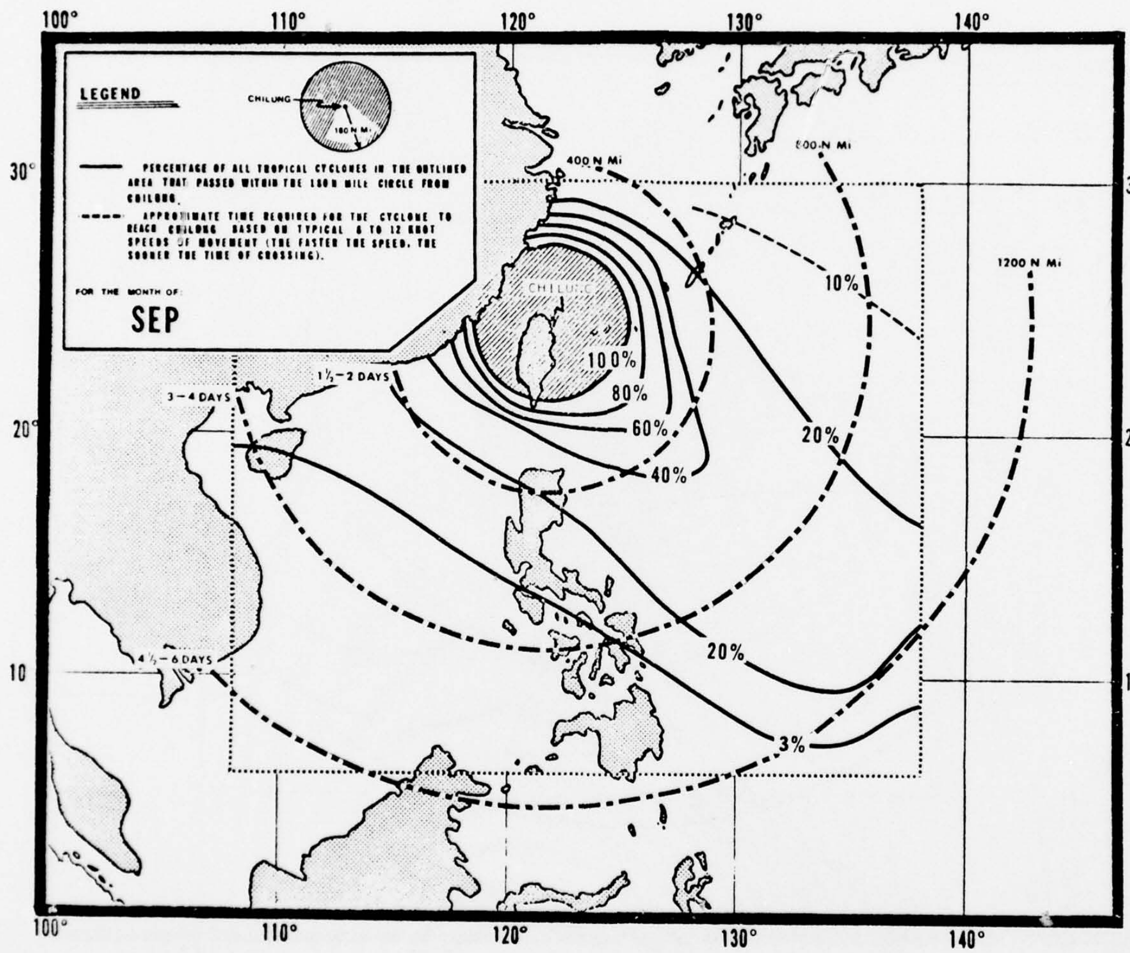

Figure III-19. Probability that a tropical cyclone will pass within 180 n mi of Chilung for the month of September (based on data from 1884-1972).

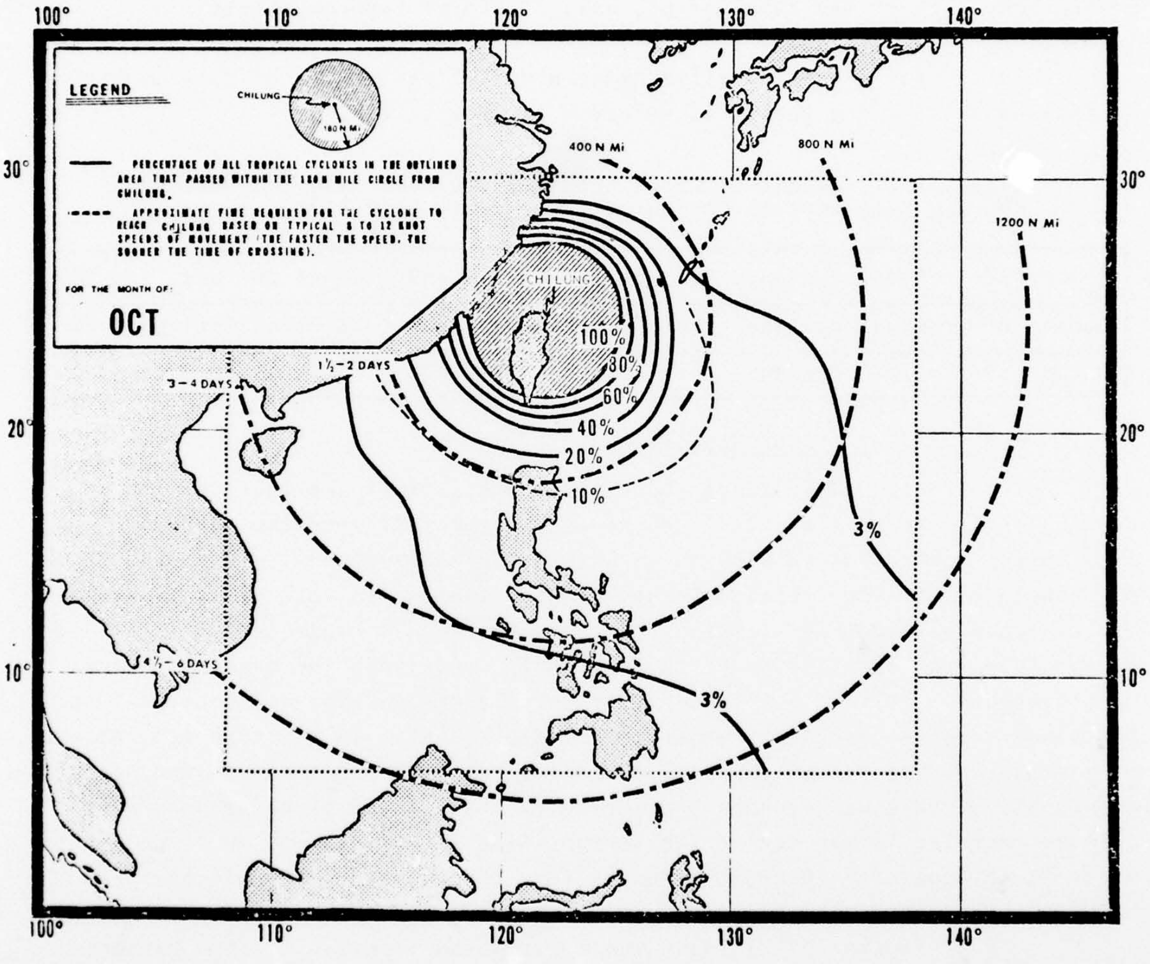

Figure III-20. Probability that a tropical cyclone will pass within 180 n mi of Chilung for the month of October (based on data from 1884-1972).

CHILUNG
(KEELUNG)

In the 24 years 1949-1972 (considering the months of June through October) an average of slightly more than 3 tropical cyclones per year passed within 180 n mi of Chilung (83 total). The largest number that occurred in any single year was six (1959 and 1966). In Table III-2 the 83 storms that passed within 180 n mi are grouped according to their effect at Chilung. It can be seen that of the total of 83, only 22 storms (approximately 27%) resulted in winds of 34 kt or greater.

For a more detailed meteorological evaluation of Chilung harbor as a typhoon haven the reader is referred to Brown, 1974.

Table III-2. Extent to which tropical cyclones affected Chilung during June through October for the years 1949-1972.

Number of tropical cyclones that passed within 180 n mi of Chilung	83
Number of tropical cyclones that resulted in winds $\geq$ 22 kt at Chilung	46
Number of tropical cyclones that resulted in winds $\geq$ 34 kt at Chilung	22

3.4.2 Effects of Topography

From analysis of the storm tracks, it is apparent that those tropical cyclones that result in gales at Chilung fall into two general categories: those that pass north of Chilung (within 180 n mi) and those that pass south of Chilung crossing Taiwan. (Note that in no case did gales result if the track was south of Taiwan.) Because Chilung is protected on three sides by mountains and open to the north, northerly winds pose the greatest threat to the harbor. This is not to say that only storms passing north of Chilung are significant -- any storm whose circulation results in a northerly component of wind at Chilung can be expected to create problems for ships in the harbor. An example of this was Typhoon Nadine (July, 1971). Nadine passed south of Chilung crossing Taiwan during the period 25 to 27 July. Late on 25 July, the winds at Chilung were recorded at 60 kt from the ENE, and wave heights near the outer harbor exceeded 40 ft.

Figure III-21 shows the position of tropical cyclone centers (1949-1972) when strong winds ($\geq$ 22 kt) were first and last recorded at Chilung. It is apparent that a significant number of the storms begin to affect Chilung when they are still over 200 n mi away. Note that storms passing to the south of Taiwan do not significantly affect Chilung. Figure III-22 shows the tropical cyclone center positions when gale force ($\geq$ 34 kt) winds were first and last recorded at Chilung. It can be seen that 34-kt winds generally do not begin until the storm is about 100 n mi away.

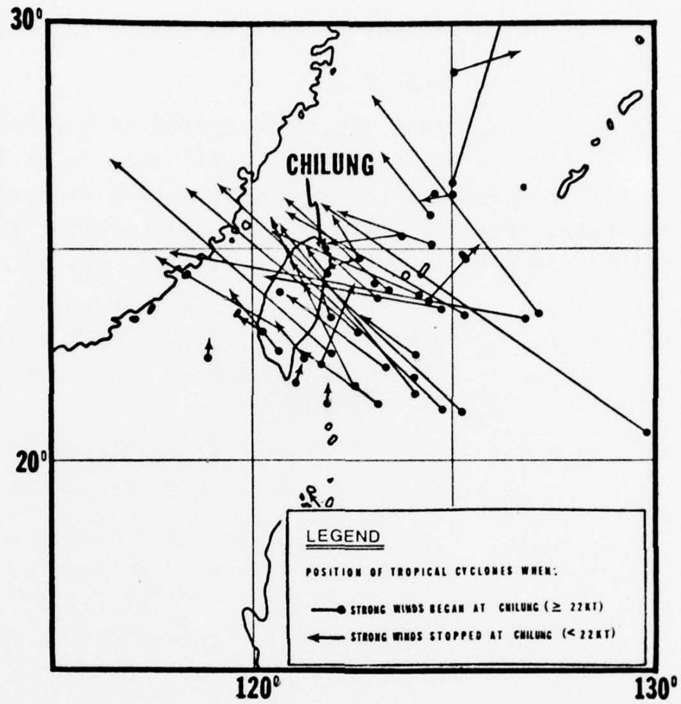

Figure III-21. Positions of tropical cyclone centers when 22 kt winds first and last occurred at Chilung (based on data from the years 1949-1972).

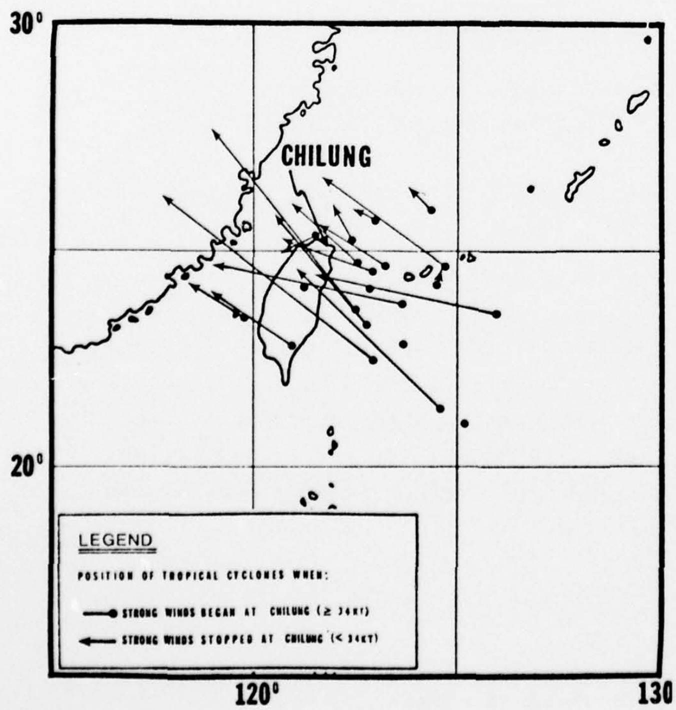

Figure III-22. Positions of tropical cyclone centers when 34 kt winds first and last occurred at Chilung (based on data from the years 1949-1972).

3.5 THE DECISION TO EVADE OR REMAIN IN PORT

3.5.1 General

A most important aspect of any decision concerning heavy weather is an early appraisal of the threat posed by an individual tropical cyclone. The preparation must begin when enough time remains to allow flexibility in the evasion plan. To facilitate early action, the following time table (in conjunction with Figure III-23) has been set up.

I. An existing tropical cyclone moves into or development takes place in area A with forecast movement toward Chilung.

   a. Review material condition of ship. A sortie may be desirable, 2-4 days hence.

   b. Reconsider any maintenance that would render the ship incapable of getting underway within 48 hours.

II. Tropical cyclone enters area B with forecast movement toward Chilung.

   a. All ships begin planning course of action to be taken if sortie should be ordered. A sortie may be desirable 1-2 days hence.

   b. Reconsider any maintenance that would render the ship incapable of getting underway within 24 hours.

III. Tropical cyclone enters area C with forecast movement toward Chilung.

   a. Execute sortie plans made in previous steps.

Due to the confined nature of the harbor, and the difficulty experienced in maneuvering a ship in strong winds, the ship should be ready to get underway before the storm center approaches within 400/600 n mi (see Figure III-23). If this general rule is followed, more than enough time will be available to clear Chilung harbor and evade before adverse weather can affect the sortie route.[4]

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[4] See section 5 of Chapter I for discussion and examples of the extent to which sea state and wind speed reduce speed of advance.

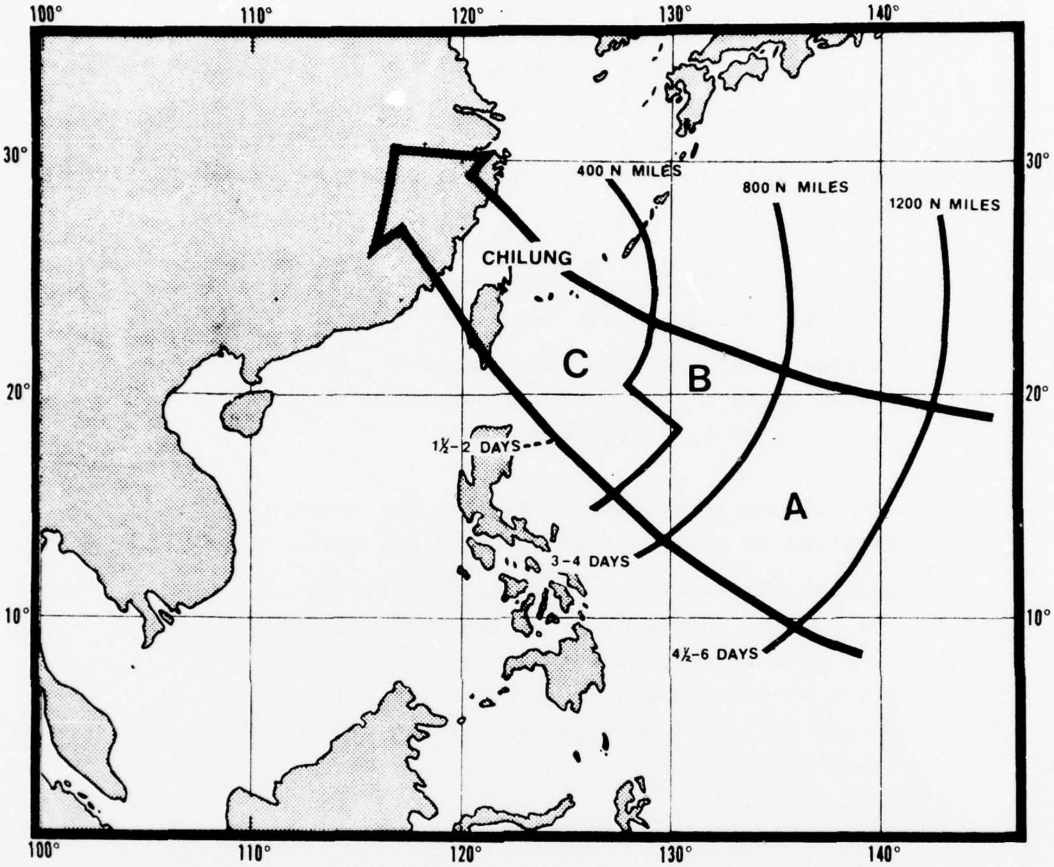

Figure III-23. Tropical cyclone threat axis for Chilung. Distance and approach times are measured from Chilung based on 8-12 kt speed of movement.

3.5.2 Remaining in Port

Chilung is a confined, crowded harbor. At any given time thirty or more merchant ships may be using its facilities. Some of these vessels may have inadequate or poorly maintained mooring gear. As a result, it is not uncommon for them to break loose during typhoon conditions causing damage to other ships in port. Because of this threat, port authorities recommend U.S. Navy ships sortie when typhoon conditions threaten. If, however, circumstances dictate the ship remain in port, every effort must be made to obtain an inner harbor berth. All harbor movements are coordinated through SOPA ADMIN and are discussed in the current SOPA ADMIN INST (5000.1 series). If an inner harbor berth cannot be obtained well prior to the onset of heavy weather, evasion at sea is strongly recommended.

3.5.3 Evasion at Sea

Evasion at sea is the preferred course of action when confronted with potential typhoon conditions at Chilung. The commanding officer, with his experience and knowledge of his unit, will always make the final evasion decisions; however, the following evasion techniques are suggested for the more common threat situations.

I. Tropical cyclone approaching from the southeast and expected to pass to the north of Chilung.

Evasion should be into the South China Sea. Sortie should begin before storm approaches within 400/600 n mi (see Figure III-23).

II. Tropical cyclone approaching from the southeast is expected to cross Taiwan south of Chilung.

Evasion should be into the South China Sea. Since the evasion path will cross the forecast track enough time must be allowed to reach a point south of the storm well ahead of the expected arrival. Sortie should begin before storm approaches within 400/600 n mi (see Figure III-23).

III. Tropical cyclone approaching from the south.

Evasion should be southeast into the Pacific Ocean (see comment (3) below).

In evading, whichever case presents itself, the following general comments should be noted:

(1) In general, evasion south through the Taiwan Strait is not recommended due to the sea state and strong winds likely to be encountered. However, if the sortie is begun as the storm enters area C (Figure III-23) enough time will be available to evade south along either coast of Taiwan.

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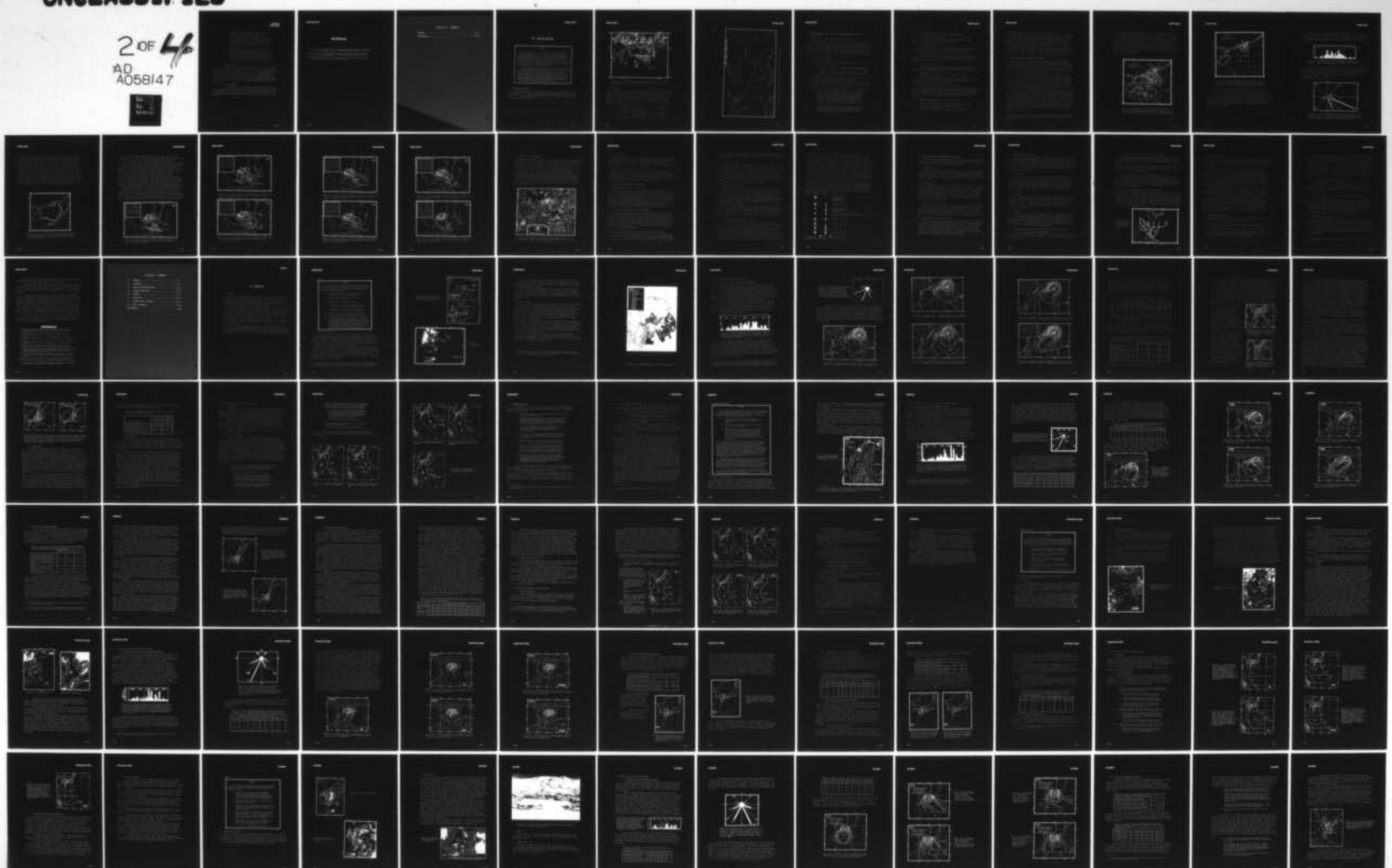

(2) Crossing ahead of an approaching typhoon is not without hazard, and must be accomplished well ahead of the typhoon. If in attempting this track crossing, the ship is caught by the wave/swell pattern ahead of the storm, the speed-of-advance may be reduced to the point that the ship will be unable to maneuver clear of the storm (see section 5 of Chapter I).

(3) It is very possible, during the peak typhoon season, for rapid storm development to occur, resulting in two or more tropical cyclones co-existing in the west Pacific area. This possibility would greatly complicate the evasion problem and should be kept in mind as evasion plans are formulated and executed.

3.5.4 Wave Action

Chilung's inner harbor has shown relatively little wave action during heavy weather. In contrast, the outer harbor consistently experiences violent wave action when northerly winds are present. Wave records for the years 1971 and 1972 indicate that under conditions of typhoon intensity northerly winds, the outer harbor can experience wave heights over 20 ft. Based on even such a limited amount of data, it is obvious that Chilung outer harbor is a completely unsatisfactory anchorage or berthing area during storm conditions.

3.5.5 Storm Surge

Storm surge, which is defined as the difference in observed water level at a given location during storm and non-storm conditions, exists to some extent in Chilung harbor. However, because of the overwhelming wave action present during typhoon conditions the relative threat posed by surge is small.

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Brown, M.E., 1974: An evaluation of the harbors of Kaohsiung and Chilung (Keelung) as typhoon havens. ENVPREDRSCHFAC Tech. Paper No. 6-74.

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SECTION IV - CONTENTS

IV HONG KONG

SUMMARY

This study of Hong Kong Harbor as a possible typhoon haven must concur with previous conclusions that the harbor can not be designated a "safe" haven in time of severe winds and waves associated with the passage of tropical cyclones. Previous results, as stated in COMSEVENTHFLT INST 5000.1H, Annex W, dated 29 Feb 1972, readily indicate that "... it is considered that Hong Kong is not a suitable haven for Seventh Fleet units." This is also in agreement with the findings of the British, that "the Royal Navy does not consider Hong Kong a suitable haven under typhoon conditions."

The first step to making a safe evasion is in recognizing that a potential threat to the port of Kong Kong exists, based on current tropical cyclone warnings (from U.S. FWC/JTWC, Guam) and a knowledge of past tropical cyclone tracks that have affected Hong Kong. Smaller ships, such as minesweepers or patrol craft, unable to outrun and evade at sea, or those ships unable to put to sea should be thoroughly familiar with the potential problems of remaining in port. It is recommended that all other Fleet units should take early decisive action to clear Hong Kong Harbor and evade at sea.

1. GEOGRAPHIC LOCATION

Figure IV-1 shows the relative orientation of the Island of Hong Kong and harbor along the China coast and the significant topographical features. Figure IV-2 is a close-up of the area outlined in Figure IV-1, showing the harbor sea lanes, moorings, and anchorages.

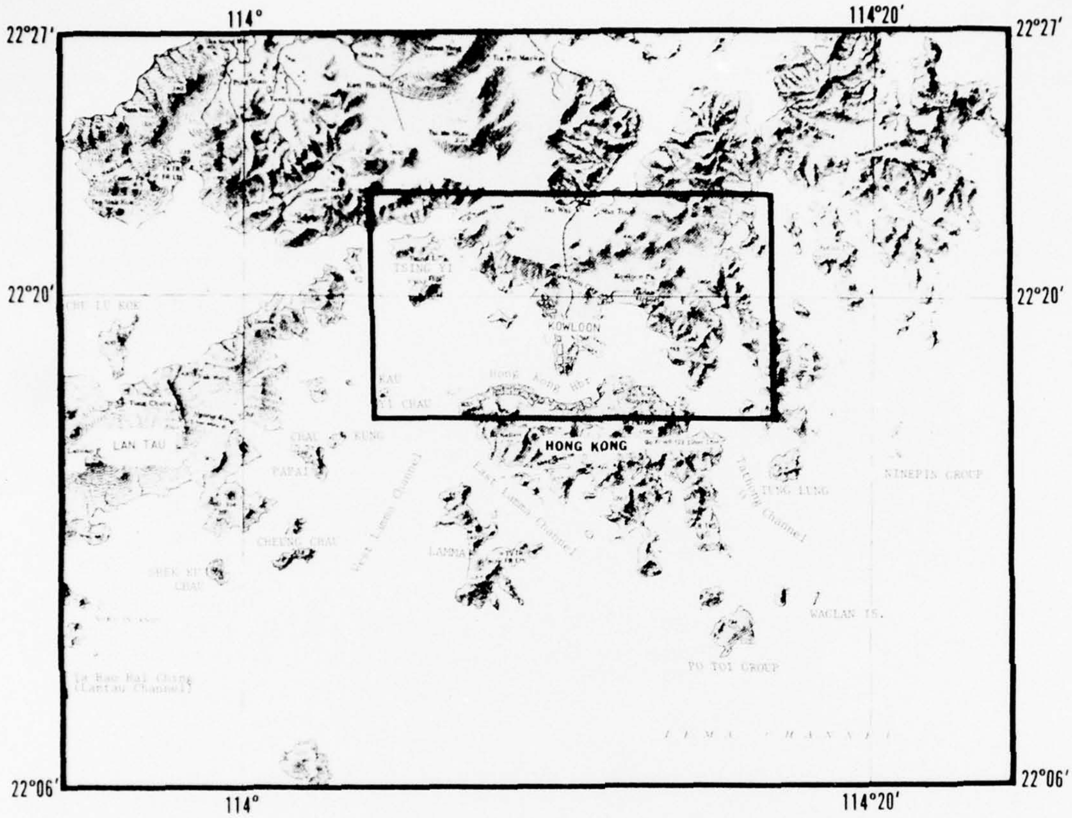

Figure IV-1. The Island of Hong Kong in relation to the China coast. (The outlined area of the harbor is enlarged in Figure IV-2.) (From DMA Hydrographic Center, 1972.)

2. THE HARBOR

The harbor of Hong Kong, located at approximately 22.3N and 114.2E, lies between the north side of Hong Kong Island and the China mainland. The harbor varies in width from one to six n mi and covers an area of 23 square n mi. The harbor and anchorage areas vary in depth from 3 to 6 fathoms, with 1 to 6 fathoms at the berth. The tidal rise varies from 3.1 to 5.3 ft. Depths of approaches and entrances to the harbor are given as follows (refer to Figures IV-1 and IV-2 for locations):

A.	East approach:	Tathong Channel	--	6½ to 10 fathoms
B.	East entrance:	Lei U Mun Channel	--	13 fathoms
C.	West approach:	West Lamma Channel	--	4½ to 5 fathoms
		East Lamma Channel	--	4½ to 10 fathoms
D.	West entrance:	Sulphur Channel	--	4 to 14 fathoms

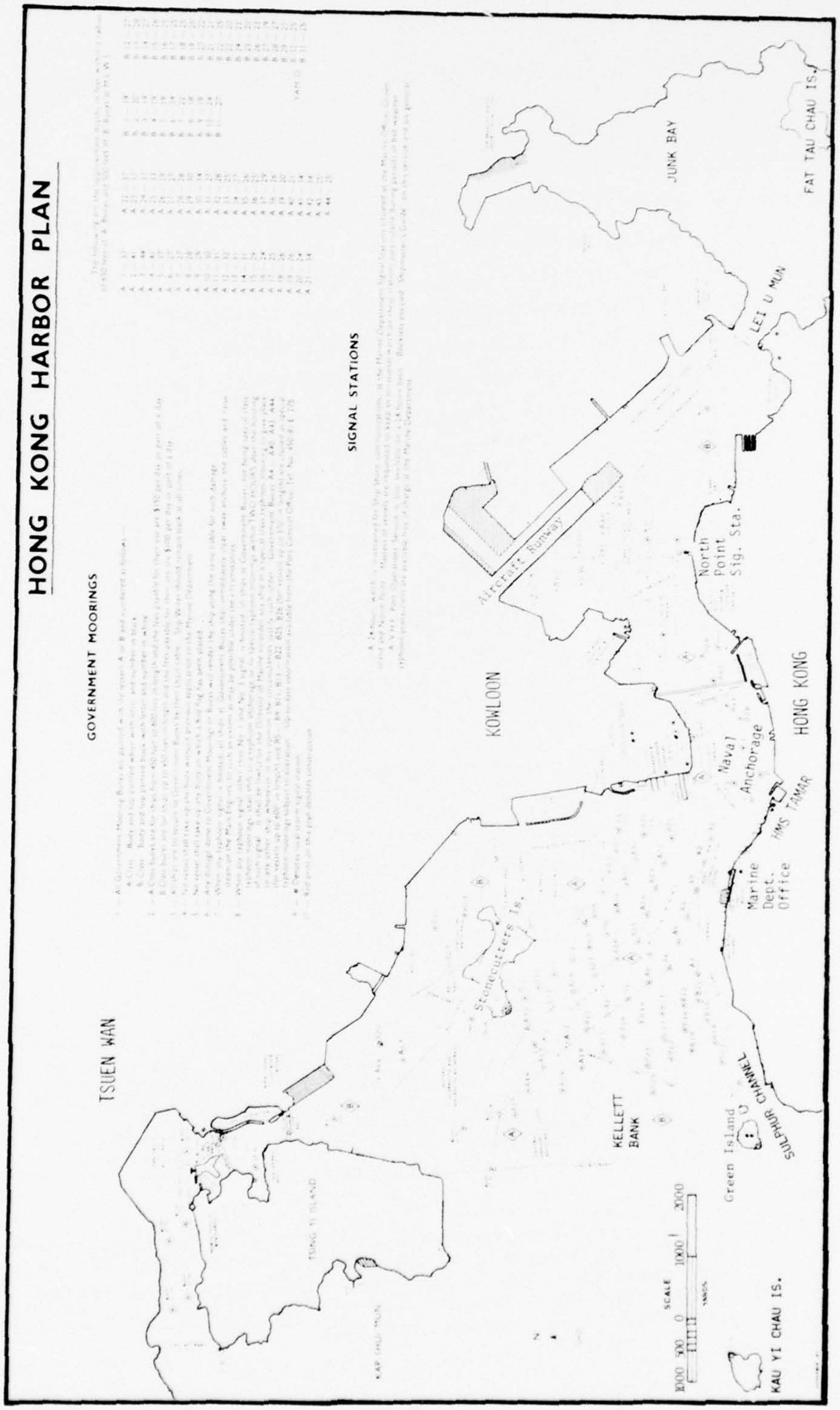

Figure IV-2. Hong Kong Harbor (from Government Publication Center, 1971).

3. PORT FACILITIES (Refer also to CINCPACFLT/COMSEVENTHFLT/MSTSFE Port Directory)

3.1 TOWAGE FACILITIES (From Marine Dept., Hong Kong, 1970)

Masters of vessels who may be required to shift berth in the event of a tropical cyclone affecting the Colony, should bear in mind that the services of tugs are at a premium immediately before and following the passing of a tropical cyclone. Tugs are then generally employed in shifting vessels to and from dockyards. Calls for towage assistance should therefore be kept to a minimum and made only in case of real emergency as when life and ships are endangered.

3.2 TYPHOON MOORINGS (From Marine Dept., Hong Kong, 1970)

A. General Classification

In Hong Kong Harbor the following moorings are, at present, approved for use as special typhoon moorings:

(1) "A" class for vessels not exceeding 600 feet (182.9 meters) in length. A 4 to A 19, A 21 to 40. A total of 36 moorings.

(2) "B" class for vessels not exceeding 370 feet (112.8 meters) in length. B 5, B 7 to B 9, B 11, B 13, B 16, B 18 to B 22 and B 26. A total of 13 moorings.

The above list is subject to amendment and up-to-date information may be obtained from the Port Control Office, Marine Department.

The distance between Government mooring buoys in Hong Kong Harbor is 1,400 feet (426.7 meters) in the case of "A" class typhoon moorings and 1,000 feet (304.8 meters) in the case of "B" class moorings.

B. Composition of Typhoon Moorings (From Marine Dept., Hong Kong, 1970)

(1) "A" class typhoon moorings are comprised of two 9-fathom lengths of 3½ inches (8.9 cm) stud link cast steel cable, with a swivel fitted between the two lengths, secured to a 90-ton concrete sinker consisting of a 50-ton base block and a 40-ton saddle. The buoy fittings, cable, swivel and shackles are tested to a strain of 247 tons when new. They are inspected every twelve months and cables are turned end for end every alternate year. The minimum size of chain permitted, with weardown, is 3 inches (7.7 cm).

(2) "B" class typhoon moorings are of a similar composition except that the size of chain is 3 inches (7.7 cm) and the concrete block is 50 tons. Components are tested to 204 tons when new and the minimum size of chain permitted is 2½ inches (6.4 cm).

3.3 NOTES ON BERTHS IN HONG KONG HARBOR IN TYPHOON SEASON

A. Alongside Berths In Naval Base

All must be vacated at the discretion of the Captain-in-Charge, Hong Kong in sufficient time to lift catamarans, etc.

B. Naval Moorings (No. 1 to 4)

All these moorings are up to the standards for typhoon moorings and may be occupied at the discretion of the Captain-in-Charge, Hong Kong.

C. Commercial A 1 to A 3, A 31 (Minimum Cable Size 2 3/4")

These are not typhoon moorings and Director of Marine requires them to be vacated within two hours of a typhoon signal other than 1 and 3 being hoisted. At such a time it may well be too late for ships to get clear to seaward.

D. Commercial B 28, A 41, A 42

These are similar to C except that they are special typhoon moorings for R.N. Patrol Craft and they are likely to be required as such anytime after Typhoon Signal No. 1 is hoisted.

E. Commercial A 4 to A 16, A 19, A 21 to A 30, A 32 to A 34 (Minimum Cable Size 3")

These are typhoon moorings for ships not exceeding 600 feet in length. Ships may be required by the Director of Marine to vacate these berths to provide room for dead ships from local shipyards.

F. Commercial A 35 to A 40 (Minimum Cable Size 3")

These are typhoon moorings for ships not exceeding 600 feet in length but are reserved for berthing dead ships from Taikoo and Kowloon dockyards and as such they would require automatic vacation on the hoisting of No. 1 Typhoon Signal. The dockyards start moving promptly and nearly always before No. 3 is hoisted.

G. Commercial B 5, B 7, B 11, B 13, B 16, B 18, B 26 (Minimum Cable Size 2½")

These are typhoon moorings for ships up to 370 feet in length.

H. Commercial - Remaining Buoys (Minimum Cable Size 2")

These are not typhoon moorings and must be vacated as in C.

3.4 TYPHOON ANCHORAGES (From Marine Dept., Hong Kong, 1970)

Junk Bay and the eastern approaches to Hong Kong Harbor are not considered to be suitable areas in which to anchor during typhoons, and there is no longer any space available in Kowloon Bay for use as a typhoon anchorage. The most popular anchorage during the passage of tropical cyclones is on or to the westward of Kellett Bank (latitude 22° 18'N, longitude 114° 06.5'E) where the depth of water varies from 3 fathoms to 12 fathoms.

When anchoring for an impending tropical cyclone, ample cable should be paid out at once without waiting until the force of the storm is felt as paying out then tends to disturb the anchor. Ships should always have their second anchor ready for letting go and use it before the winds reach gale force.

4. TROPICAL CYCLONE CLIMATOLOGY FOR HONG KONG

The "season" for tropical cyclones for Hong Kong is from June through October, although gale force winds (average wind speed 34-47 kt) associated with the passage of tropical cyclones have been recorded as early as the 19th of May and as late as the 23rd of November. Tropical cyclones can and do occur at any time of the year, but the storms in the "off season" (November through May) have seldom affected the port of Hong Kong in the past.

Climatological statistics indicate that five or six tropical cyclones threaten Hong Kong each year and require the hoisting of the Number One local storm warning signal,[1] with one of these storms coming near enough to cause gale force winds (34-47 kt). On the average, once in every ten years the center of a fully developed typhoon passes sufficiently close to the harbor to provide sustained typhoon force winds (>63 kt) and cause severe damage to shipping in the harbor as well as local inland flooding. This does not, however, preclude the occurrence of such a storm during any particular year.

If the center of a tropical cyclone passes to the south and crosses the south China coast to the west of Hong Kong, winds locally will be generally from the east or southeast with gale conditions (34-47 kt) possible for several hours, providing Hong Kong comes under the direct wind circulation of the storm. If the center of a typhoon moves northward to the east of Hong Kong, winds will be from the north to northwest and gales are less likely, unless the storm is intense or passes relatively close to Hong Kong. In addition, rainfall can be expected to be quite heavy in the former case (a typhoon passing to the west of Hong Kong), compared to relatively lighter amounts of precipitation when a typhoon passes to the east of Hong Kong.

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[1] Definition of Storm Signal 1: "A tropical cyclone is centered within about 400 n mi of Hong Kong and may affect Hong Kong." Storm signals are listed in Figure IV-16.

Local warning bulletins and forecasts are issued regularly by the Royal Observatory Hong Kong (ROHK) whenever a local wind warning signal is hoisted.

Figure IV-3 shows the positions of tropical cyclone centers when first and last strong winds (≥22 kt) occurred at the Royal Observatory Hong Kong (ROHK) on Kowloon. Data from 1936-1964 (29 years) were used in obtaining Figure IV-3. Similarly, Figure IV-4 shows the positions of tropical cyclones when the first and last gales (winds ≥34 kt) occurred at the Royal Observatory. In both figures the dot ("•") symbolizes the position of the tropical cyclone when strong winds (Figure IV-3), or gale force winds (Figure IV-4), began and the "arrow ("←") the position when the winds ended.

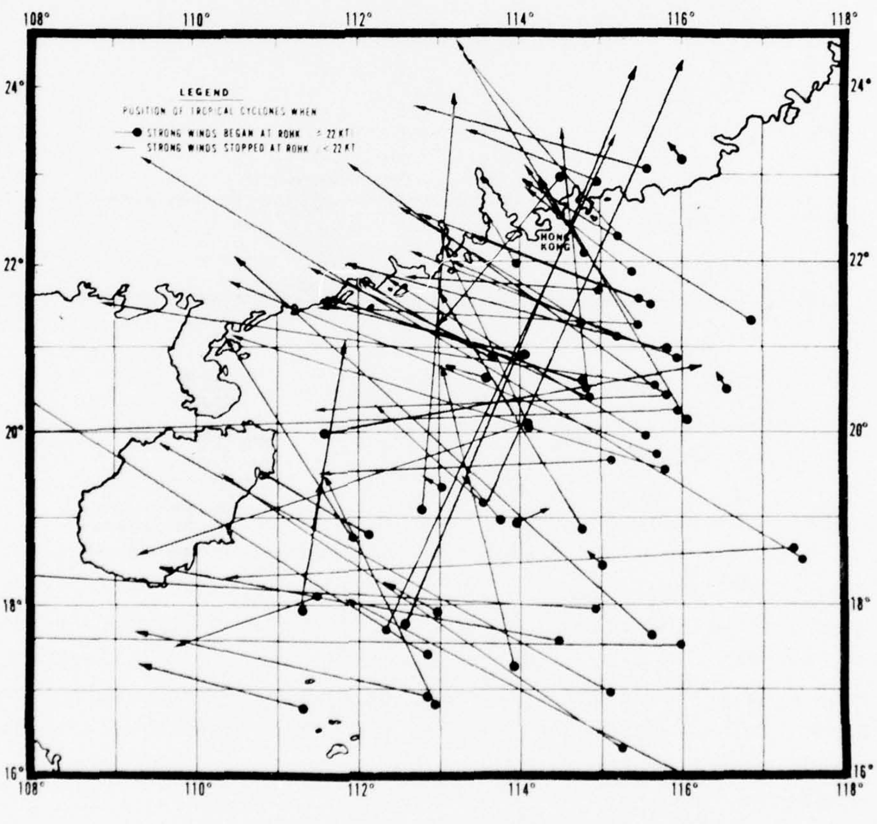

Figure IV-3. Positions of tropical cyclone centers when first and last strong winds (≥22 kt) occurred at the Royal Observatory, Hong Kong (ROHK). (Based on available data from 1936 to 1964, from Royal Observatory, Hong Kong, unpublished.)

HONG KONG

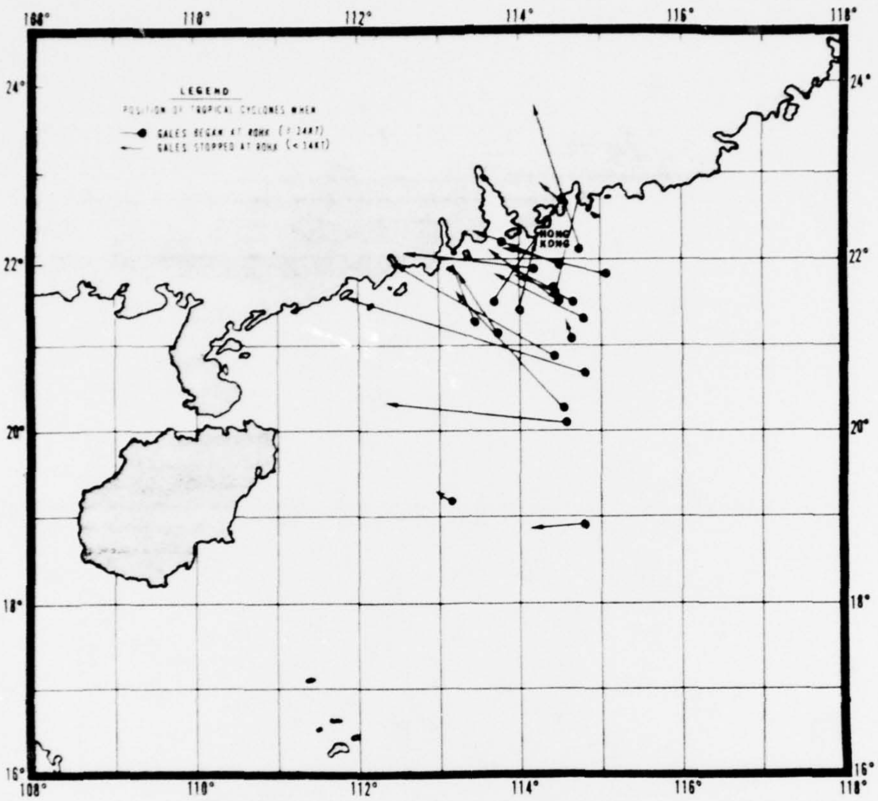

Figure IV-4. Positions of tropical cyclone centers when first and last gale force winds ($\geq$34 kt) occurred at the Royal Observatory, Hong Kong (ROHK). Based on available data from 1936 to 1964. (From Royal Observatory Hong Kong, unpublished.)

For the most part, the onset of strong winds ($\geq$22 kt) occurs as the tropical cyclones cross 116E moving on a general westerly or northwesterly track. The onset of gale force winds ($\geq$34 kt) occurs as the storms cross 115E and is generally associated with the tropical cyclones approaching within 90 n mi. Note that very few tropical cyclones passing to the north and east of Hong Kong give strong or gale force winds to Hong Kong. Even though approximately 40% of the tropical cyclones passing within 180 n mi of Hong Kong pass to the north, many of these storms weaken rapidly as they move inland and do not present a severe threat to Hong Kong.

Figure IV-5 shows the frequency distribution for the number of typhoons and tropical storms which created gale conditions in Hong Kong. These are grouped into 5-day periods and are based on 62 years of data (1884-1941; 1946-1949). Note the overwhelming frequency of occurrence in the months of July, August, and September.

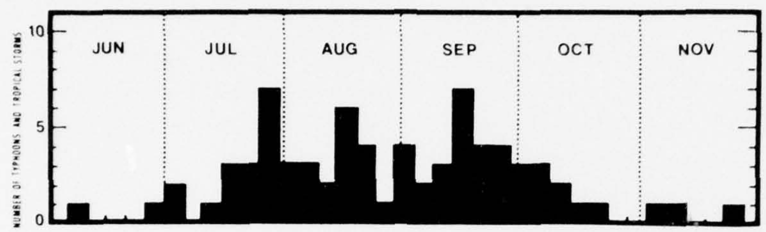

Figure IV-5. Frequency distribution of the number of typhoons or tropical storms giving gale force conditions to Hong Kong for 5-day periods. Based on 62 years of data. (From Heywood, 1950.)

Figure IV-6 shows the average direction of approach to Hong Kong of the 62 typhoons and tropical storms considered previously and the percentage frequency of these approaches for each octant of the compass. Approximately 95% of these tropical cyclones approached Hong Kong from the east through the south. The length of each line is proportional to the number of occasions on which the cyclones approached from a given octant.

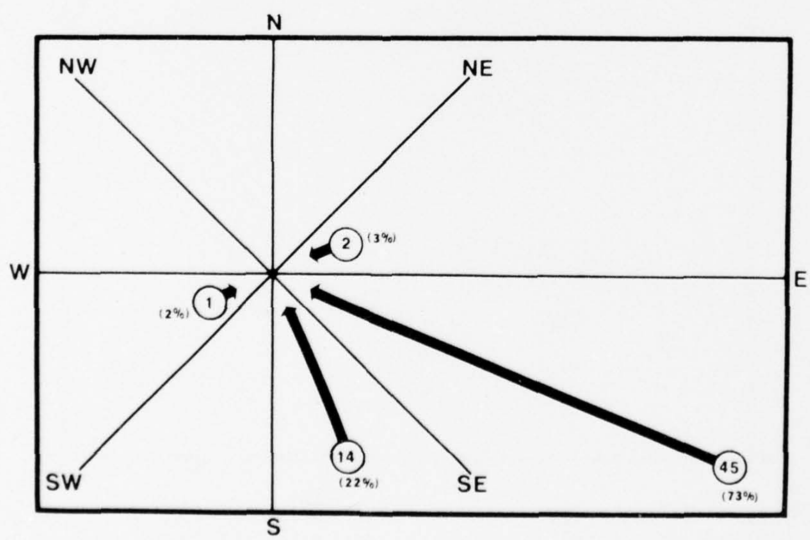

Figure IV-6. Direction of approach to Hong Kong of typhoons and tropical storms. (The length of each line is proportional to the number of occasions on which typhoons and tropical storms approached from each octant of the compass.) (From Heywood, 1950.)

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Figure IV-7 relates the mean distance and bearing of tropical cyclones from Hong Kong when strong winds ($\geq$22 kt) were first recorded at the Royal Observatory Hong Kong (ROHK) (see Figure IV-2) and winds $\geq$28 kt were first recorded at Waglan Island (located 2 n mi southeast of the southern tip of Hong Kong Island as seen in Figure IV-1). The mean positions of the tropical cyclone centers were computed from 32 years of data (1936-1967). Note that tropical cyclones passing to the south or approaching from the south caused strong winds at Hong Kong and Waglan Island sooner than from any other direction of approach. In addition, the stronger winds recorded even earlier at Waglan Island demonstrates the effect of the topography in causing decreased winds inland at ROHK compared to the open ocean surrounding Waglan Island. The large variation between Waglan and ROHK for the commencement of strong winds from tropical cyclones bearing to the east of Hong Kong additionally demonstrates the role of topography in delaying the onset of the strong winds at ROHK.

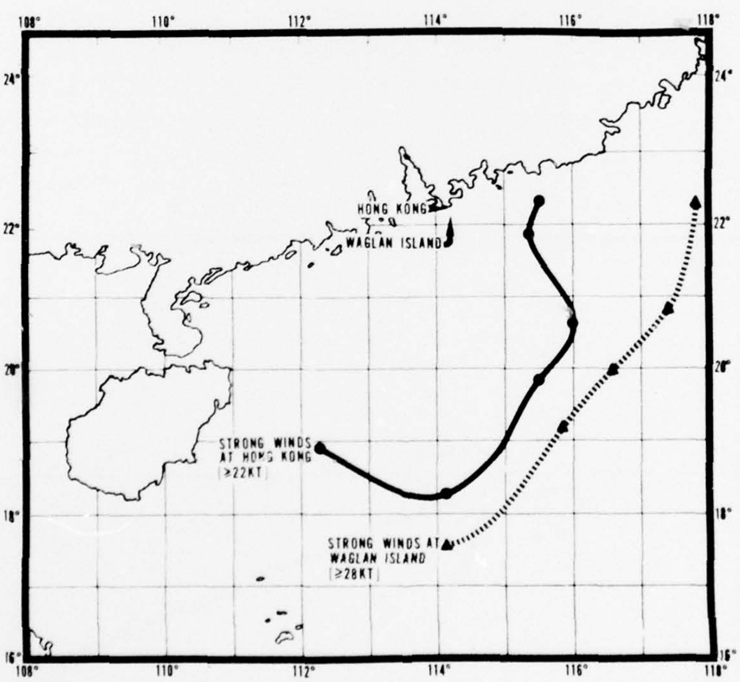

Figure IV-7. Bearing and mean distance of tropical cyclone centers which gave rise to first reported strong winds at the Royal Observatory, Hong Kong (solid line) and at Waglan Island (dashed line).

In order to determine the probability of a tropical cyclone in the Philippine Sea or South China Sea affecting Hong Kong and its surrounding region at some future time, 87 years of tropical cyclones were examined.

Figures IV-8 through IV-14 have been analyzed with respect to the percentage of tropical cyclones which have passed within the 180 n mi semicircle to the south-southeast of Hong Kong (this can be interpreted as the probability of "threat"). In addition, the approximate time required for the cyclone to reach Hong Kong is shown, based on typical speeds of movement of from 8 to 12 kt (the faster the speed, the sooner the time of reaching Hong Kong).

For example, Figure IV-8 shows, for the month of May, that of all the tropical cyclones over the 87 years of data that crossed over the Northern Luzon area of the Philippine Islands, approximately 10% entered the semicircle 180 n mi from Hong Kong. Additionally, those tropical cyclones which reached Hong Kong did so within about 2½ days. For a more detailed meteorological evaluation of Hong Kong Harbor as a typhoon haven, see Mautner and Brand (1973).

A problem more peculiar to Hong Kong than many other ports in WESTPAC is the rapid building of seas at the entrance to the harbor. Adequate time must be allowed to clear the harbor in order to avoid these high seas and gain maneuvering room in the open ocean. Wave heights over 30 ft have been observed during typhoon conditions just outside Hong Kong Harbor and wave heights of over 20 ft have been observed for intense tropical cyclones even hundreds of miles away.

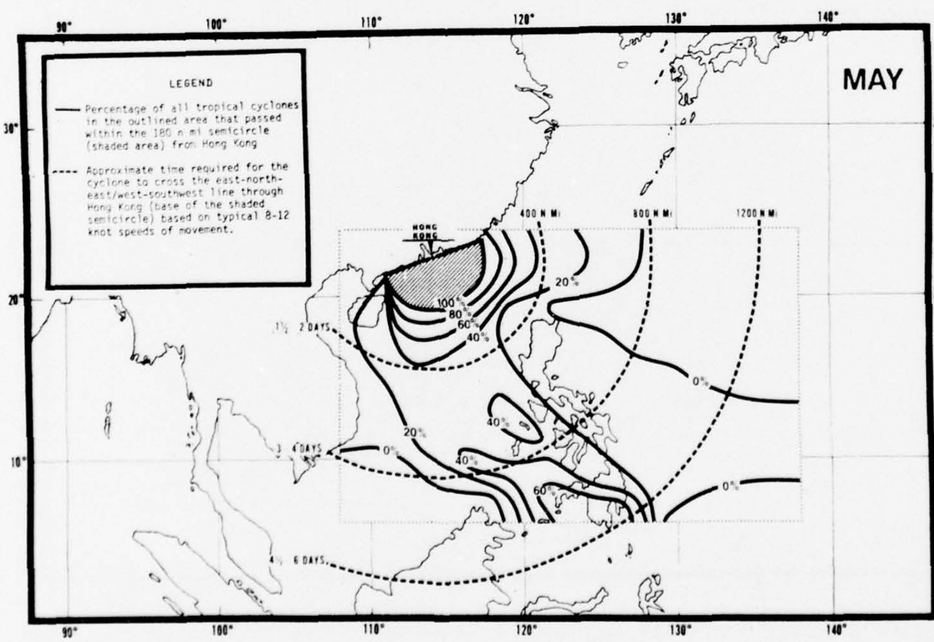

Figure IV-8. Probability that a tropical cyclone will pass within 180 n mi of Hong Kong (shaded area) for the month of May. (Based on 87 years of data.)

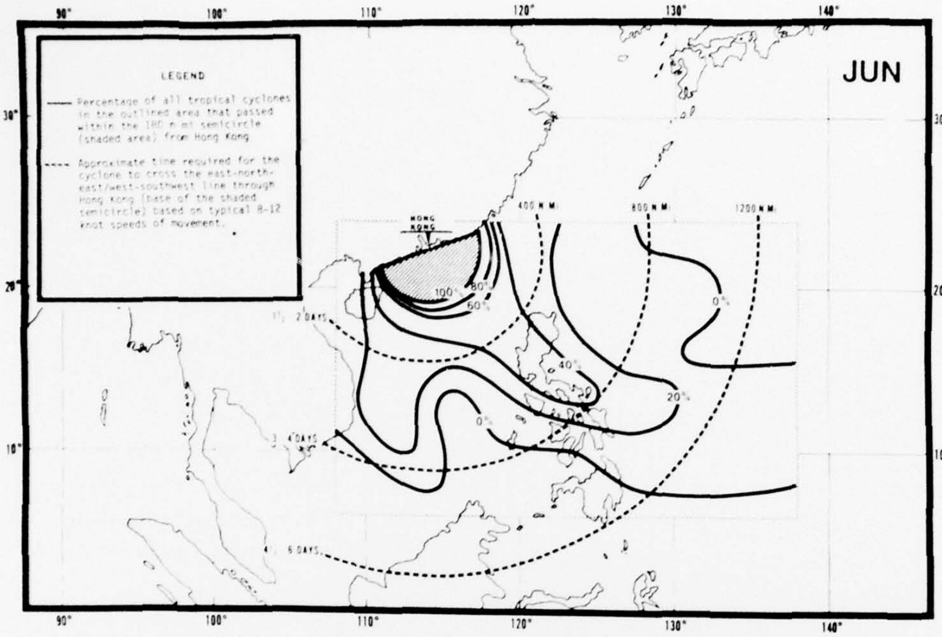

Figure IV-9. Probability that a tropical cyclone will pass within 180 n mi of Hong Kong (shaded area) for the month of June. (Based on 87 years of data.)

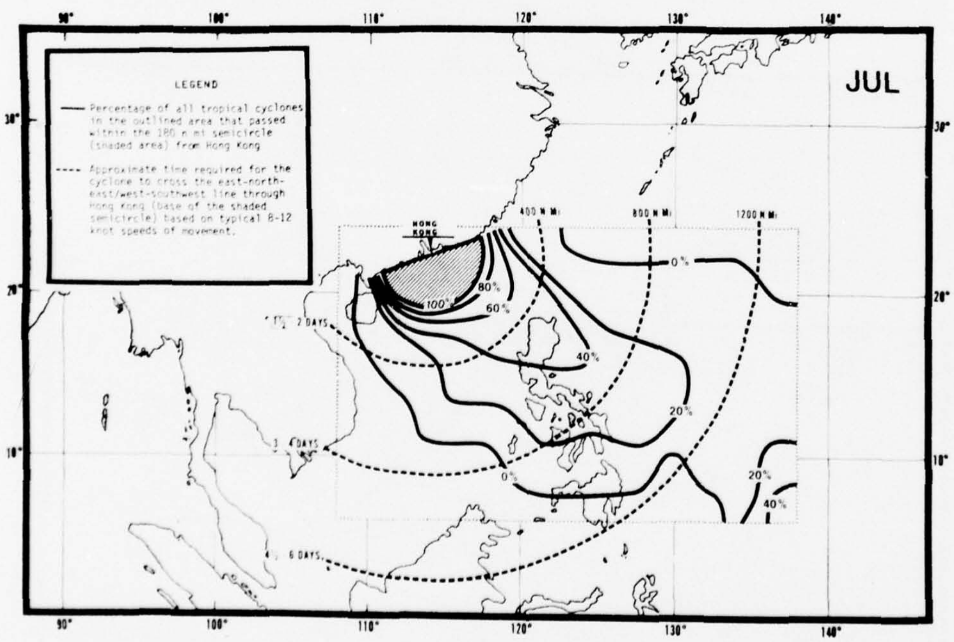

Figure IV-10. Probability that a tropical cyclone will pass within 180 n mi of Hong Kong (shaded area) for the month of July. (Based on 87 years of data.)

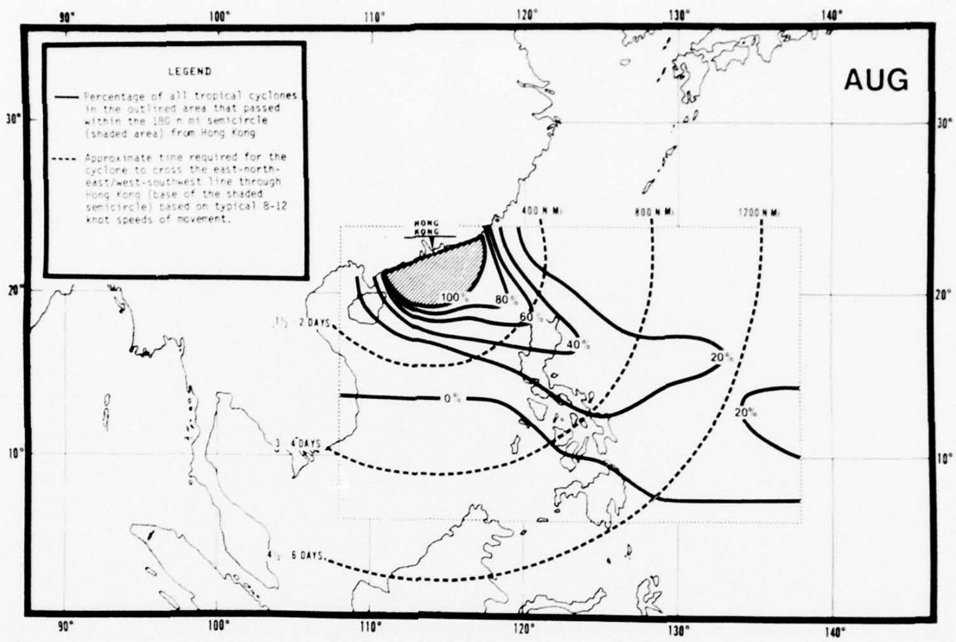

Figure IV-11. Probability that a tropical cyclone will pass within 180 n mi of Hong Kong (shaded area) for the month of August. (Based on 87 years of data.)

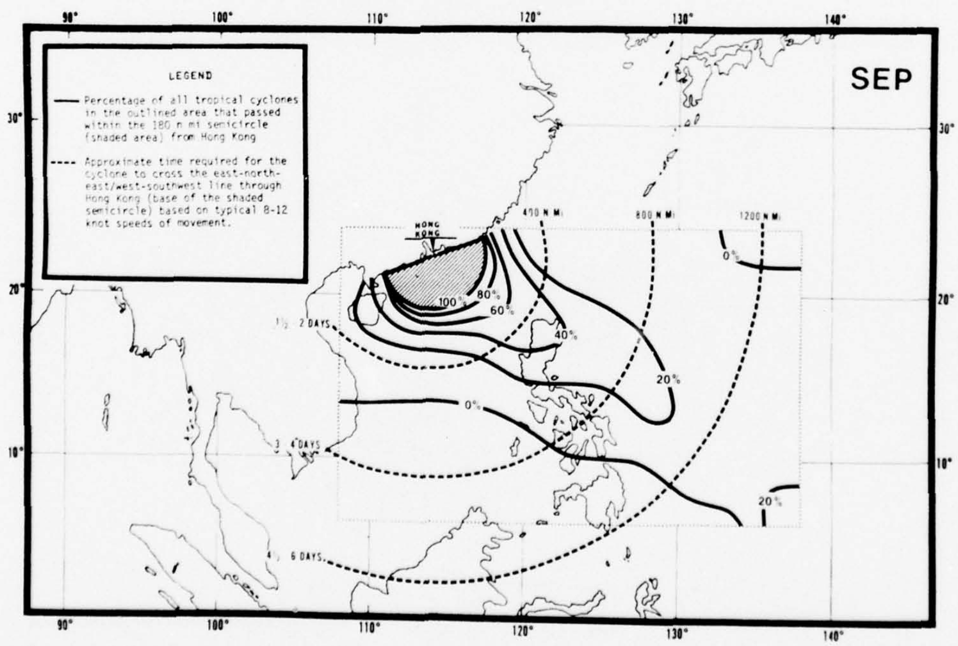

Figure IV-12. Probability that a tropical cyclone will pass within 180 n mi of Hong Kong (shaded area) for the month of September. (Based on 87 years of data.)

HONG KONG

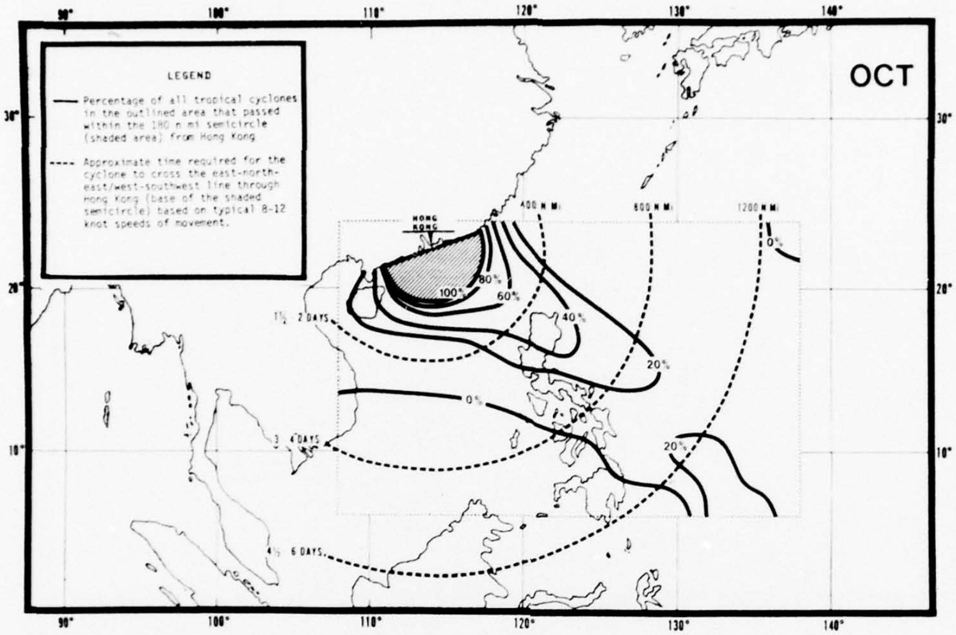

Figure IV-13. Probability that a tropical cyclone will pass within 180 n mi of Hong Kong (shaded area) for the month of October. (Based on 87 years of data.)

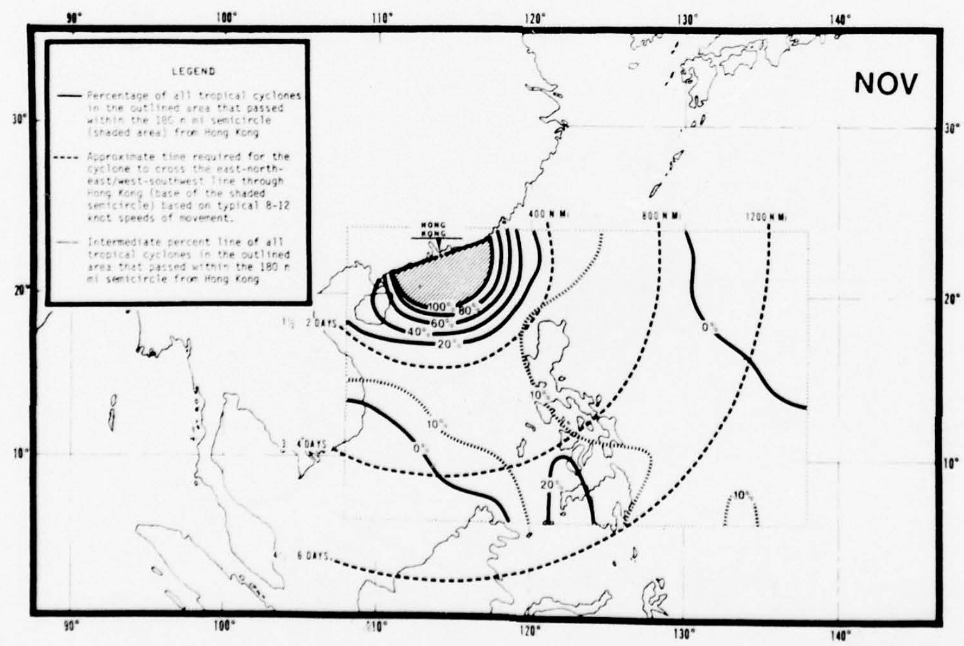

Figure IV-14. Probability that a tropical cyclone will pass within 180 n mi of Hong Kong (shaded area) for the month of November. (Based on 87 years of data.)

5. INFLUENCE OF THE TOPOGRAPHY

Figure IV-15 shows the general east-west orientation of the ranges of hills on both Hong Kong Island and Kowloon. This orientation tends to somewhat channel the winds from approaching tropical cyclones to a general east-west component, even though the circulation of the storm may suggest a more northerly or southerly wind. Figure IV-15 also shows the three basic harbor anchorage areas: Western Anchorage, Middle Harbor, and Eastern Anchorage and Junk Bay.

General notes on the geography of the south China coast and Hong Kong, and its effect on the wind field of tropical cyclones have been obtained from LCDR A. M. Morrice, Royal Navy, Base Meteorological Officer to the Commodore-in-Charge, from 1970-1973. Briefly, Morrice discusses the three anchorage areas (Figure IV-15) and describes general conditions in each area as a direct result of the passage of a tropical cyclone from various directions relative to Hong Kong (Morrice, 1973a):

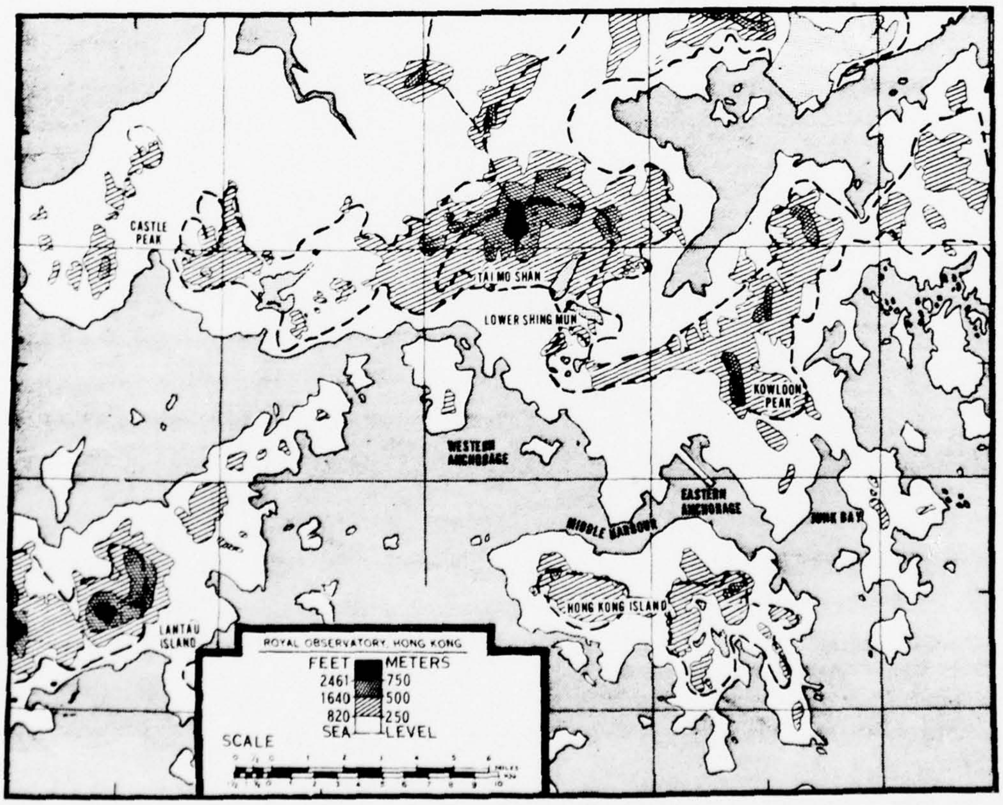

Figure IV-15. Topography of Hong Kong and surrounding area. (The grid is the Universal Transverse Mercator Grid with the grid lines every 10 kilometers.) (From Morrice, 1973a.)

5.1 GENERAL GEOGRAPHY

The south China coast lies east-northeast to west-southwest from the Taiwan Strait to the Luichow Peninsula. It forms a rugged and well-indented coastline with a multitude of small islands. In adverse weather conditions it is a dangerous shoreline. Inland, major mountain ranges run approximately east-west.

5.2 GEOGRAPHY OF HONG KONG (Refer to Figure IV-15)

The main topographical features of Hong Kong are two ranges of hills. Over the New Territories in the north, a well marked ridge runs from east to west from Kowloon Peak to Tai Mo Shan and Castle Peak. Approximately 8 miles south of this is another ridge, again orientated east-west, consisting of Hong Kong Island itself and Lantau Island, broken by a gap of about 6 n mi.

6. TROPICAL CYCLONES AFFECTING HONG KONG

6.1 TROPICAL CYCLONE TO THE SE OF HONG KONG

The vast majority of tropical cyclones approach Hong Kong from the southeast. The *resultant* winds are from the north and, because of the rugged terrain to the north, the winds experienced locally are less severe than might otherwise be expected. Any tropical cyclone running inland over 50 n mi east of Hong Kong is likely to have little effect on the harbor. However, as the circulation moves north and weakens, there is often an increase of wind strength from the southwest. This will affect Western Anchorage in particular, which has a long fetch towards the south and may therefore experience destructive seas.

6.2 TROPICAL CYCLONE PASSING S TO SW OF HONG KONG

As the bearing changes from S to SSW the local winds will veer to the east. Because of the east-west orientation of the hills, there is a well marked tendency for the winds to remain easterly in Middle Harbor and Western Anchorage even as the bearing of the tropical cyclone becomes SW or even SSW (provided the center is over about 150 n mi from Hong Kong). In Junk Bay the wind will probably change suddenly to southeasterly and increase with a rapid build-up of wave height under these conditions. In such a situation all sections of the harbor will be exposed and dangerous.

6.3 TROPICAL CYCLONE MOVING NORTH PASSING TO THE WEST OF HONG KONG

Provided the landfall is between 50 and 150 n mi west of Hong Kong, winds are unlikely to veer beyond southeasterly, and so Western Anchorage and Middle Harbor will be relatively sheltered, while Eastern Anchorage and Junk Bay would

become more exposed. However, once the circulation has hit land winds may become south or southwesterly, as in paragraph 6.1, with a sudden increase in Western Anchorage.

6.4 DIRECT HIT OR CLOSE PASS

Any tropical cyclone passing within 25 n mi to the east and 50 n mi to the west of Hong Kong will have a serious effect on all areas of the harbor. Storm surge can cause dangerous rises in sea level. Sea walls and piers have been known to be awash when the surge coincided with a high tide. Within the harbor the sea becomes very confused with short steep waves. Should the wind go south or southwest, dangerous conditions prevail in Western Anchorage. Obviously, the closer the center passes to Hong Kong, the greater is the effect on the harbor. Unfortunately, there is no particular area of the harbor which could be considered as favorably situated under such conditions.

7. STORM SURGE IN THE HARBOR

The natural harbor of Hong Kong, like any other harbor, is subject to "storm surge" effects as the tropical cyclone approaches landfall. Storm surges can be defined as the difference between the observed water level during the storm and that which would have occurred at the same time and place in the absence of the storm. Tropical cyclones in the past have yielded storm surges in Hong Kong Harbor from 2-6 ft. Storm surges, coinciding with high tide, can cause a serious rise in the water level resulting in the sea walls and piers becoming awash (Morrice, 1973a).

"Seiche" effects, or the natural period of oscillation between the harbor and incoming swell wave, that can produce a rapid rise and fall of the water level does not appear to be a significant problem in the open-ended harbor of Hong Kong. Additionally, since the harbor is open to both the east and west, it acts to dissipate, to some extent, the seiche and storm surge amplitude (Watts, 1959).

8. THE DECISION TO EVADE OR REMAIN IN PORT

The key to a safe evasion lies in an awareness that a threat to the harbor exists. Tropical cyclones which cross the northern portion of the Philippines into the South China Sea and finally strike the China coast have, in the past, had a relatively high probability (37-56% throughout the typhoon season) of passing within the 180 n mi, over-ocean semicircle from Hong Kong. Sorties from Hong Kong must be made early in order to gain maneuvering room in the open ocean. Within 24 hours of a tropical cyclone crossing the Philippine Islands, swells can be generated that can severely hamper a ship's speed-of-advance

although the storm may still be a great distance from Hong Kong. In the case of Typhoon Rose (August, 1971), even with the center of the storm 100 n mi south of Hong Kong, maximum seas in excess of 30 ft were observed by a wave recorder at Waglan Island (at the eastern approach to the harbor). These seas were measured approximately 14 hours before Typhoon Rose struck the China coast just outside the harbor. Consequently, sortie action even 14 hours prior to the Closest Point of Approach (CPA) to Hong Kong of Typhoon Rose, with 30-ft seas at the entrance to the harbor, would have been very hazardous to say the least.

Decisive action must be taken early. Recalling all hands or enough critical personnel to sortie and clear the harbor is an extremely important part of getting out of Hong Kong Harbor in time to evade. The heavy swells produced at the entrance to the harbor as a result of a typhoon crossing into the South China Sea can make a late sortie extremely dangerous.

ROHK advisories are available to all ships in port at Hong Kong via the harbor net circuits. Information and bulletins are also broadcast at frequent intervals by domestic radio stations. As the tropical cyclone nears Hong Kong, local radar can yield an excellent fix of the center position if the cyclone is well defined. Storm signals displayed in the harbor are shown in Figure IV-16.

Signal Number	Day Signal (black shapes)	Night Signal *(lights)	Meaning
1.	T	○ ○ ○	A tropical cyclone is centered within 400 n mi which may later cause strong wind, gale, storm or typhoon force winds in the Hong Kong area.
3.	⊥	◉ ○ ◉	A strong wind (average wind speed 22-33 kt) is expected.
8NW.	▲	○ ◉ ◉	Gale or storm force winds (average wind speed 34-63 kt) are expected from the NW quadrant.
8SW.	▼	◉ ○ ○	Gale or storm force winds are expected from the SW quadrant.
8NE.	▲ ▲	◉ ◉ ○	Gale or storm force winds are expected from the NE quadrant.
8SE.	▼ ▼	○ ○ ◉	Gale or storm force winds are expected from the SE quadrant.
9.	▼ ▲	◉ ◉ ◉	An increase in wind force is expected.
10.	✚	● ◉ ●	Typhoon force winds (over 63 kt) are expected from any direction.

*NOTE: ○ = white light ◉ = green light ● = red light (The above signals should not be confused with the strong monsoon black ball, night signal = white, green, white)

Figure IV-16. Hong Kong storm signals.

9. ROYAL NAVY CRITERIA FOR BERTHING AND EVASION

The Royal Navy utilizes the following criteria for berthing and evasion as described by LCDR Morrice, Royal Navy, Base Meteorological Officer, Office of the Commodore-in-Charge, Hong Kong (Morrice, 1973b):

9.1 INTRODUCTION

The Royal Navy does not consider Hong Kong a suitable haven under typhoon conditions. The normal Naval policy is for warships of frigate displacement and above to put to sea in sufficient time for adequate evasion to be possible. Smaller units (patrol craft and coastal minehunters) normally secure to buoys in Victoria Harbor.

9.2 ALONGSIDE BERTHS

It is a matter of policy that no HM ship remains alongside. The quay walls in the Naval Basin are considered too low because of the possibility of storm surge reinforcing high tides. Experience has shown that the sea in Victoria Harbor becomes very confused with short steep waves. There is photographic evidence that the quay walls can be awash under typhoon conditions. Serious bumping with major damage and capsize resulting are considered very real consequences of staying alongside.

9.3 NAVAL BUOYS (See Figure IV-2)

Numbers 1 and 2 Naval buoys are up to the standard for typhoon moorings and may be occupied at the discretion of Commodore Hong Kong by ships up to 600' in length; however, they invariably have to be vacated for use by the resident RN Patrol Craft. Numbers 3 and 4 buoys are only suitable for Patrol Craft or ships of CMS (coastal minesweeper) size in typhoon conditions.

9.4 GOVERNMENT BUOYS (See Figure IV-2)

Buoy B 28 is normally used as a patrol craft typhoon mooring and as such may have to be vacated at an early stage. Buoys A 4-A 40, A 43 and A 44 are classed as special typhoon moorings for ships up to 600' in length. Buoys B 5-B 9, B 11, B 13-B 22, B 25, and B 26 are classed as special typhoon moorings for ships up to 370' in length. All these buoys may be required by the Director of Marine who may order them to be vacated at any time. Their classification is subject to alteration at short notice.

9.5 ANCHORAGES (See Figure IV-2)

Despite the quality of the bottom, anchoring in either Eastern or Western Anchorages is considered undesirable. In every major typhoon since the war a considerable number of ships have broken adrift from moorings and anchorages; these drifting hulks then present a deadly threat to ships in their path. The tragic loss of nearly 80 lives on the SS FATSAN in Typhoon Rose (August 1971) was attributed to some extent to collisions with ships which had broken adrift and were not under command.

9.6 NOTICE FOR SEA

The nature of the coastline makes imperative an early departure if a real threat is in the offing. The effect of sailing on morale must take second place under these conditions to the potential loss of, or severe damage to, operational units. During the period May-October, all HM ships in Hong Kong not under maintenance are required to be at 4 hours notice for sea and must be able to recall sufficient duty personnel to take the ship to sea within that time limit.

9.7 MAINTENANCE

Ships under maintenance present a special problem, but here again the basic approach is the same. Repairs have to be suspended in order that ships may proceed to sea. Only limited docking facilities are available and, being commercial, there is no guarantee that space will be available "on the day." In extreme situations, large ships have been towed to buoys and secured there to ride out the storm.

9.8 CONCLUSION

The overall policy is to "retain flexibility." This often entails decisions at an early stage when the magnitude of the threat is unknown and difficult to predict. However, adequate planning at this time can prevent the disastrous consequence of being unable to react in the way one would have wished to at a later stage. It is considered essential to take precautions and be prepared early, and then stand down should the threat diminish.

9.9 NORMAL SEQUENCE OF EVENTS WITH A SLOW BUILD UP (See Figure IV-17)

The times given are for an 8-12 kt movement.

A tropical cyclone in Area A (Figure IV-17) (or even a potential development in Area A) with a meteorological situation which indicates a possible movement towards Hong Kong:

(a) The material state of all ships will be reviewed.

(b) Those fully operational will be warned that a situation may develop in 2-4 days which could necessitate sailing. This will be passed to liberty men with particular reference to any whose families have come to join them in Hong Kong.

(c) Ships under maintenances will be considered more carefully. Any at 48 hours notice will require a decision, even at this early stage, if flexibility of action is not to be lost later.

9.10 TROPICAL CYCLONE MOVES INTO AREA B (See Figure IV-17)

Should the meteorological situation still indicate a threat to Hong Kong, then ships under maintenance at 24 hours notice require a decision at this stage. Fully operational ships will start planning what course of action they will take should sailing be ordered. This aspect will be considered in more detail in a later paragraph.

9.11 TROPICAL CYCLONE ENTERING AREA C (See Figure IV-17)

All the plans made during the previous stages now go into effect. Provided adequate action has been taken in the preceding days, flexibility to cope with the threat as it increases is retained. Ships intending to sail will proceed. The smaller units will secure to their typhoon buoys before winds locally reach 20 knots. Experience has shown that considerable difficulty can be encountered in securing with wind above this speed. At about the same time the Naval Base will be secured to "typhoon stations."

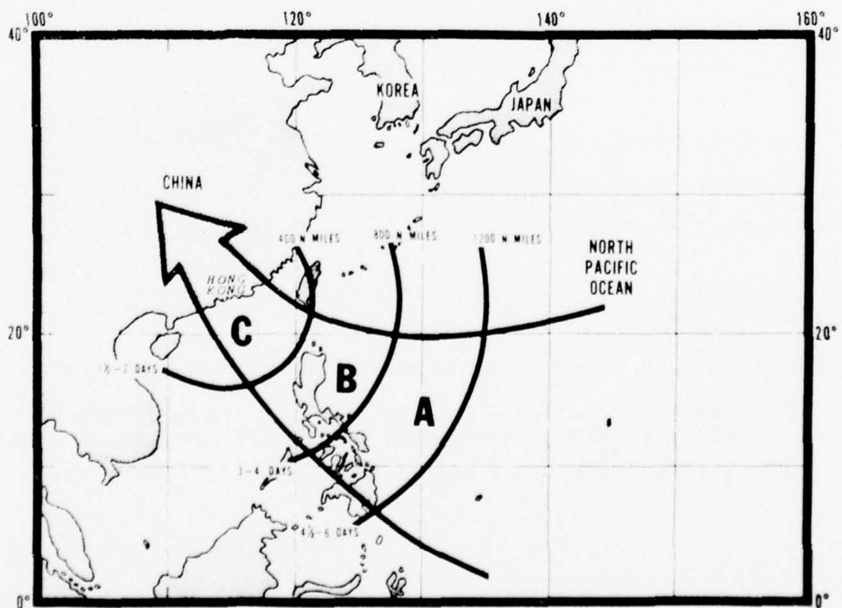

Figure IV-17. Tropical cyclone area of concern for Hong Kong. (From Morrice, 1973b.)

9.12 AVOIDING ACTION AT SEA

The decision to sail, once taken, poses the new problem of the best course of action once at sea. This section is based on the experience of the past few years. However, the commanding officer on the spot, with his detailed knowledge of ship and crew, must always make his own personal decision as the situation dictates.

The most common case is the tropical cyclone which crosses the northern Philippines or moves through the Bashi Channel on a west-northwest course. Should a passage close to Hong Kong be predicted and sailing ordered, the normal procedure is for the ships to sail southwest to cross ahead of the typhoon into the southern "safe" semicircle. Provided sailing is early enough, the winds and seas will not have got up, and good progress can be made as the prevailing winds will be northerly. Ship design must be considered however. In 1971, a Leander class frigate (with a low stern) experienced considerable difficulty in making way with stern wind and seas.

An uncommon situation would be a typhoon moving northeast towards Hong Kong having recurved over the western part of the South China Sea. Here ships would sail to the southeast to cross ahead of the typhoon's track. Wind and sea would be against the ship, and progress would be likely to be slow.

The most difficult case occurs when a typhoon moves north towards Hong Kong, and much depends on the meteorological situation. The "safe" semicircle lies to the west, but the coastline falls away to the west-southwest towards Hainan Island. To the east, in the "non-navigable" semicircle, the coastline falls away to the ENE, and an easterly course results in a steady increase in sea room. If recurvature towards the NE is likely, however, this course is most dangerous. However, should recurvature have a low probability, this may well be the best action to take.

10. CONSIDERATIONS FOR EVASION

Noteworthy points regarding evasion at sea, stressed by Morrice, deal with three basic directions of threat by a tropical cyclone:

10.1 A TROPICAL CYCLONE APPROACHING FROM THE SOUTHEAST AFTER CROSSING LUZON, P.I.

This case occurs most often and requires two major criteria for evasion:

(1) Early sailing on a southwest track in order to cross well ahead of the tropical cyclone into the "safe" semicircle; and

(2) a ship which rides fairly well in a following sea.

Crossing ahead of a typhoon is a serious matter not to be treated lightly. However, Somervell and Jarrell (1970) indicated that one of the most successful tactics in the Pacific involves crossing of the "T", that is, running downwind and down-sea ahead of the typhoon in order to cross the track and reach a position south of the storm. It is emphasized that "crossing of the track" must be done well in advance. If not, the speed-of-advance of the ship may be hampered due to severe seas and swells, and the ship will be helplessly trapped in the direct path of the oncoming typhoon.[2] This tactic should not be attempted unless it can be managed outside the area covered by the expanded radius of 30-kt winds, i.e., the danger area (Somervell and Jarrell, 1970).

10.2 A TROPICAL CYCLONE APPROACHING FROM THE SOUTHWEST (after recurvature or development over the South China Sea)

Again, early departure by a ship on a southeasterly track is the key in order to avoid as much as possible the head-on winds and seas that will significantly reduce any intended speed-of-advance. However, according to climatology (Figure IV-6), a tropical cyclone approaching from the southwest is less likely to occur.

10.3 A TROPICAL CYCLONE APPROACHING FROM THE SOUTH TOWARDS HONG KONG (as with Typhoon Rose)

This is undoubtedly the greatest threat to the harbor and unfortunately the most difficult to evade. There is little choice but to run an initial course of 090° True in order to obtain sea room in which to maneuver. This course is only acceptable, however, if recurvature towards the northeast is unlikely. Otherwise, a ship could be easily trapped in the path of the storm.

Any of the above decisions are difficult to make, but it is incumbent upon the local commander to make a decision and make it early.

11. CONSIDERATIONS FOR REMAINING IN PORT

The following problem areas and considerations should be taken into account if the decision is made to remain in the harbor (which would apply to smaller ships, such as patrol craft or minesweepers unable to outrun and evade at sea, or those ships unable to put to sea):

A. The possibility exists, at the discretion of the Captain-in-Charge, of having to vacate the typhoon buoys on short notice for a less desirable spot in Western Anchorage.

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[2] See Figure I-4 for graphs of ship's reduced speed-of-advance versus sea-state conditions.

B. The danger of ships broken adrift and out of control doing considerable damage in the tight quarters of the harbor is a threat.

C. Securing to buoys should be done before winds reach greater than 20 kt locally in order to prevent undue difficulty in securing. Note that a tropical cyclone bearing 180° (170°-190°) from Hong Kong (due south) on the average will produce winds in the harbor greater than or equal to 22 kt at a mean distance of 242 n mi.

D. The holding action of the bottom in the anchorages, although good, can not be expected to prevent dragging in winds of typhoon intensity. In the case study of Typhoon Rose, the USS REGULUS (AF-57) experienced extreme anchor drag prior to grounding, even though steaming to the anchor. Figure I-5 provides a rough means to determine required steaming to the anchor to ease the strain. However, it should be cautioned that the use of engine power when the ship is yawing severely may only accentuate the yaw and worsen the situation instead of easing it. Shipboard radar should be used to establish fixes and obtain relative positions to determine the amount of anchor drag encountered.

E. Storm surge effects as a result of a typhoon moving inland may result in the increase of the mean water level of 2 to 3 ft above normal. This increase may be as high as 6 ft above normal with storm surge coinciding with high tide and strong southeasterly winds.

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SECTION V - CONTENTS

V JAPAN

1. GENERAL

Japan is an island nation in the western part of the North Pacific Ocean off the eastern coast of the Asiatic mainland consisting of a chain of islands extending in an arc from northeast to southwest. The four main islands of Japan from north to south are Hokkaido, Honshu, Shikoku and Kyushu. Hundreds of smaller islands lie off the coasts of the main ones.

Honshu is the largest of the main Japanese Islands. Yokosuka, a major port city in southeast Honshu, is used continuously by the U.S. Navy. It is currently homeport for a number of SEVENTH Fleet units. The Numazu Operating Area in south central Honshu is used routinely by the U.S. Navy. Additionally commercial shipping firms utilize three small harbors in the Numazu area. Iwakuni and Kure are located in the southwestern region of Honshu.

Kyushu is the third largest and the southernmost major island land mass of Japan. The two major ports of interest for the U.S. Navy on this island are Sasebo and Kagoshima.

Okinawa is located approximately 350 n mi south of Kyushu and has two major ports of interest to Department of Defense vessels, Buckner Bay and Naha.

A detailed description of the coasts and harbors of Honshu and Kyushu and Okinawa can be found in the Sailing Directions (Enroute) for Japan, Pub. No. 156.

2. YOKOSUKA

SUMMARY

The conclusion reached in this study is that the port of Yokosuka is a "safe" typhoon haven; a port in which to remain if already there or in which to seek shelter if at sea when threatened by a typhoon. The primary factors in reaching this conclusion are:

(1) The port provides shelter from wind and sea due to the surrounding land masses.

(2) Wave action induced by typhoons has been negligible in the port.

(3) Storm surge has negligible effect.

(4) The orientation of the berths and drydocks with respect to the local topography is good.

(5) The experience level and the high degree of competence of the Port Services personnel.

(6) The only situation in which the port would not be a safe haven is when a very intense typhoon ($\geq$120 kt) passed directly over Yokosuka.

(7) The history of the port. Conversations with Japanese employees at Fleet Activities, Yokosuka indicated that since 1945 there is no recollection of U.S. Navy, Japanese Maritime Self Defense Force or merchant ships sortieing from the port of Yokosuka due to a typhoon. It should be noted however that the port has never been truly tested as a haven by U.S. Navy aircraft carriers.

2.1 LOCATION AND TOPOGRAPHY

The port of Yokosuka is located at 35°17'N, 139°40'E in the central part of the Miura Peninsula on the southwest side of landlocked Tokyo Bay. The harbors of Yokohama and Tokyo are also in Tokyo Bay and Figure V-1 locates some pertinent features. Tokyo Bay penetrates the southeast coast of Honshu in a northerly direction for a distance of almost 35 n mi. Approximately 200 ships transit Uraga Suido, the entrance to Tokyo Bay, daily.[1]

The terrain immediately adjacent to Tokyo Bay is low, but to the west and northwest are high mountains. The island of Honshu is one of the most rugged of land areas (see Figure V-2). The mountains in the north central area average 5,000 to 10,000 ft in height and are often called the Japanese Alps. The highest mountain, Fujiyama (12,395 ft), is located 60 miles due west of Yokosuka. Northern Honshu is less mountainous.

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[1] Uraga Suido is a controlled traffic route, one of several controlled routes established by the Japanese Maritime Safety Agency to regulate shipping traffic in highly congested areas in an effort to avert marine accidents.

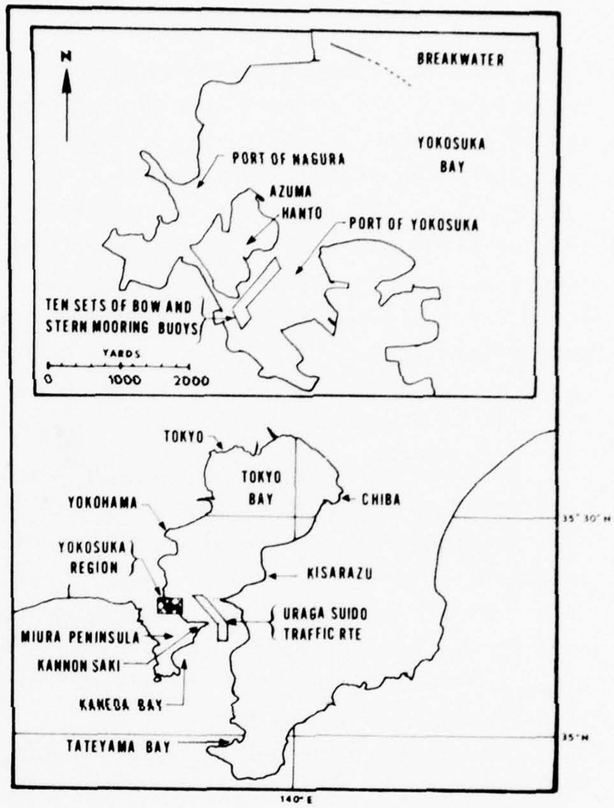

Figure V-1. Tokyo Bay and the surrounding land area. The Yokosuka region is enlarged at the top of the figure.

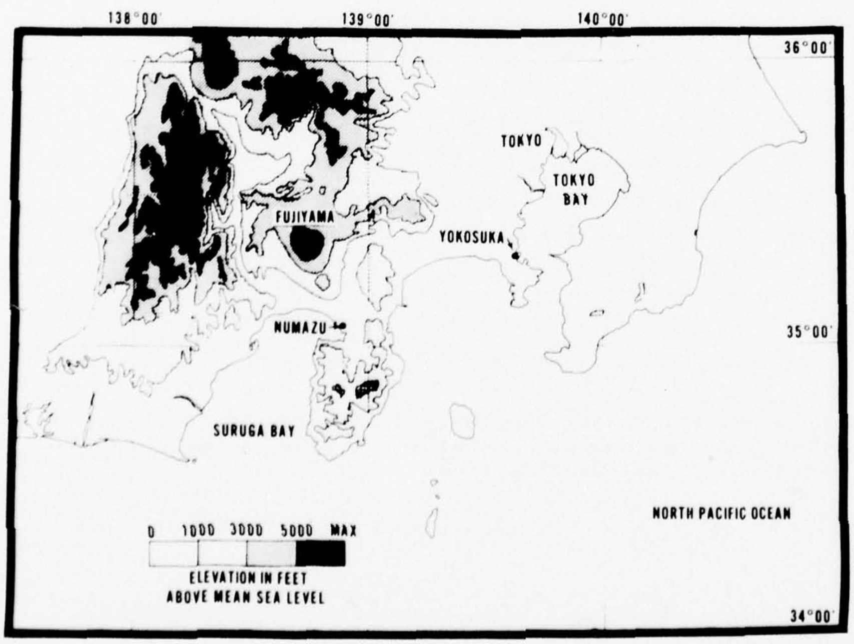

Figure V-2. Topography of central Honshu.

Note the relative flatness of the terrain north and east of Yokosuka as compared with the terrain to the west and northwest. Southern Honshu is even less jagged with no peaks rising over 5,000 ft. The rugged terrain of Honshu influences the weather at Yokosuka.

Yokosuka Bay is at the southwestern end of the inner part of Tokyo Bay. The harbor of Yokohama, a large commercial port, is about 10 n mi northward of Yokosuka Bay. Tokyo Harbor is about 20 n mi north-northeastward of Yokosuka. The harbor of Yokosuka can be classified as a medium-sized harbor of the coast breakwater type.

2.2 YOKOSUKA HARBOR

Yokosuka Harbor is entered from the southern part of Tokyo Bay. The harbor is bounded on the east by part of the Miura Peninsula which is the site of U.S. Fleet Activities (FLEACTS) Yokosuka, and on the west by Azuma Hanto which is actually an island. Azuma Hanto separates Yokosuka Harbor from Nagura Harbor which is used by the Japanese Maritime Self Defense Force (JMSDF) and is a commercial port. Nagura Harbor is entered from the southwestern part of Yokosuka Bay. A small, narrow channel separates Azuma Hanto at its southwestern end from the mainland.

The entrance to the harbor of Yokosuka is about 500 yards wide between the 5-fathom curves. Depths in the harbor decrease from 11 fathoms at the entrance to less than 5 fathoms near the head. A pilot is required when proceeding into or out of drydocks and their services are recommended when a vessel exceeds 5000 tons and/or has a single screw. The harbor can accommodate about 20 ships of various types at any one time.[2]

Figure V-3 is a photograph of Yokosuka Harbor which shows the local topographical features in the immediate vicinity of the port of Yokosuka. Note the protection afforded berths 8, 9, 10, 11, and 12 and drydock 6 from northerly winds clockwise to southerly direction winds.

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[2]The trend toward larger ship types has reduced the pierside berthing capacity inside the port. The optimum load out for the port has been suggested as 1 CVA, 1 CLG and 14-18 other various ship types.

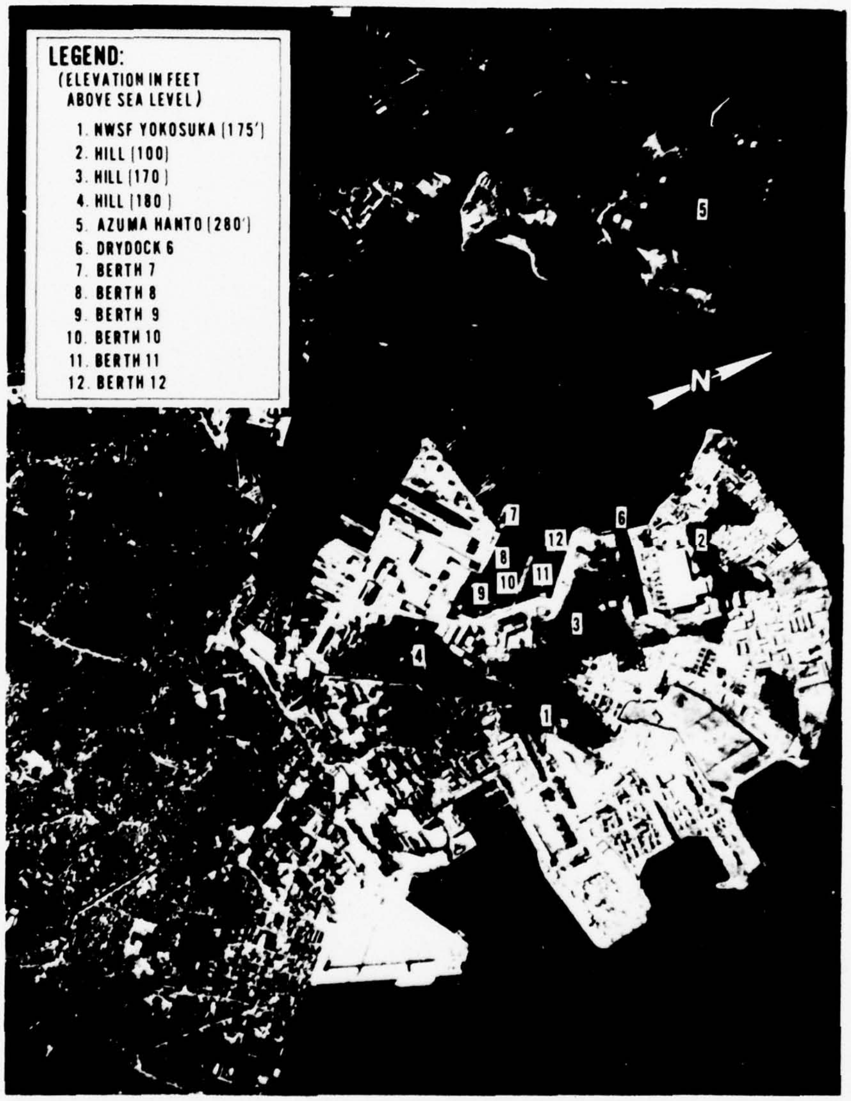

Figure V-3. Aerial photograph of the Port of Yokosuka.

2.3 TROPICAL CYCLONES AFFECTING YOKOSUKA

2.3.1 Tropical Cyclone Climatology for Yokosuka

Tropical cyclones which affect Yokosuka generally form in an area bounded by the latitudes 5N and 30N and the longitudes 120E and 165E. The latitudinal boundaries shift poleward during the summer months and then equatorward in winter in response to the seasonal changes of the synoptic environment.

In the genesis area mentioned above typhoons have occurred in all months but, with rare exceptions, those affecting the main Japanese Islands are confined to the period of May to November. Late summer and early autumn are the likeliest seasons. Size and intensity of the storms vary widely.

The majority of those that pose a threat to Yokosuka (any tropical cyclone approaching within 180 n mi of Yokosuka is defined as a "threat" for the purpose of this study) occur during the months June-October. Figure V-4 gives the frequency distribution of threat occurrences by 5-day periods. This summary is based on data for the 27 years 1947-1973. Note that the maximum number occur during August and September.[3]

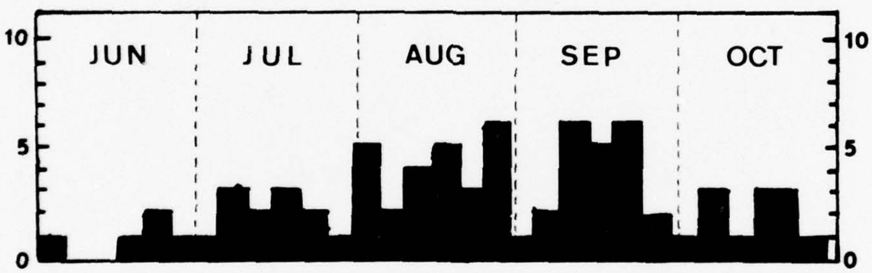

Figure V-4. Frequency distribution of the number of tropical cyclones that passed within 180 n mi of Yokosuka. Subtotals are based on 5-day periods for tropical cyclones that occurred during 1947-1973.

Figure V-5 depicts, on an 8-point compass, the "threat" tropical cyclones according to the octant from which they approached Yokosuka. The circled numbers indicate the total that approached from an individual octant. The count for an octant of approach includes both recurvers (northeasterly direction of movement at CPA) and non-recurvers. Note that a majority of these approach from the south-southwest and west-southwest. A more detailed inspection of the sample of 76 tracks revealed that only 9 (12%) did not recurve before passing within 180 n mi of Yokosuka.

[3] A total of 82 tropical cyclones passed within 180 n mi of Yokosuka during the May-November period for the years 1947-1973. Seventy-six (93%) of these tropical cyclones passed within 180 n mi during the 5 months, June-October, and the remaining 6 passed in the months of May and November, 3 in each month.

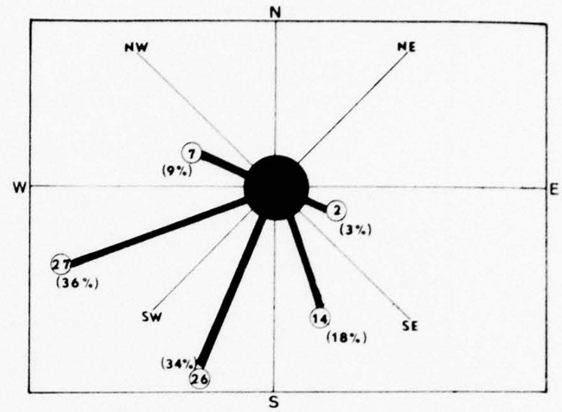

Figure V-5. Octant from which tropical cyclones (June-October, 1947-1973) approached to within 180 n mi of Yokosuka. Circled numbers indicate the number that approach from each octant. The number in parenthesis is the percentage of the total sample of 76 that approached from that octant

Figures V-6 to V-10 present the percentage of tropical cyclones that have passed within 180 n mi of Yokosuka (can be interpreted as a probability of threat) for the months June-October. The solid lines show a "percent threat" for any tropical cyclone location within the area examined. The dashed lines represent the approximate time in days for a system to reach Yokosuka. For example, in Figure V-6, a tropical cyclone located at 28N, 136E has approximately a 50% probability of passing within 180 n mi of Yokosuka and will reach Yokosuka in about one day.

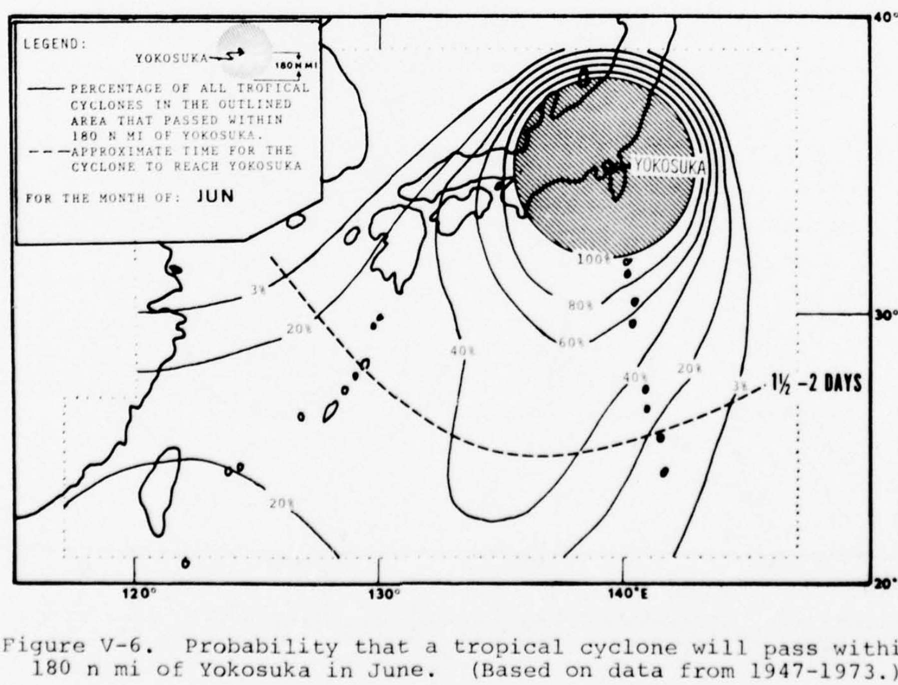

Figure V-6. Probability that a tropical cyclone will pass within 180 n mi of Yokosuka in June. (Based on data from 1947-1973.)

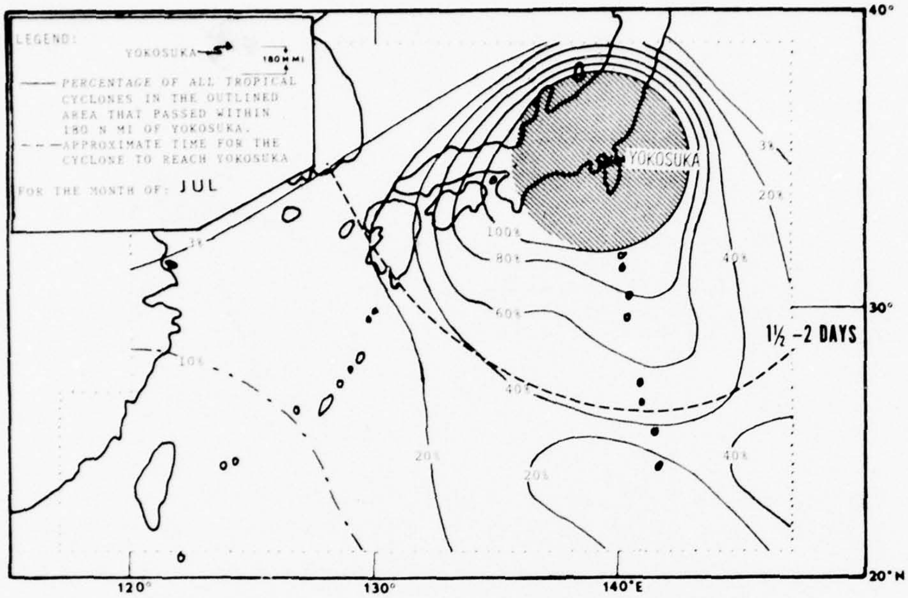

Figure V-7. Probability that a tropical cyclone will pass within 180 n mi of Yokosuka in July. (Based on data from 1947-1973.)

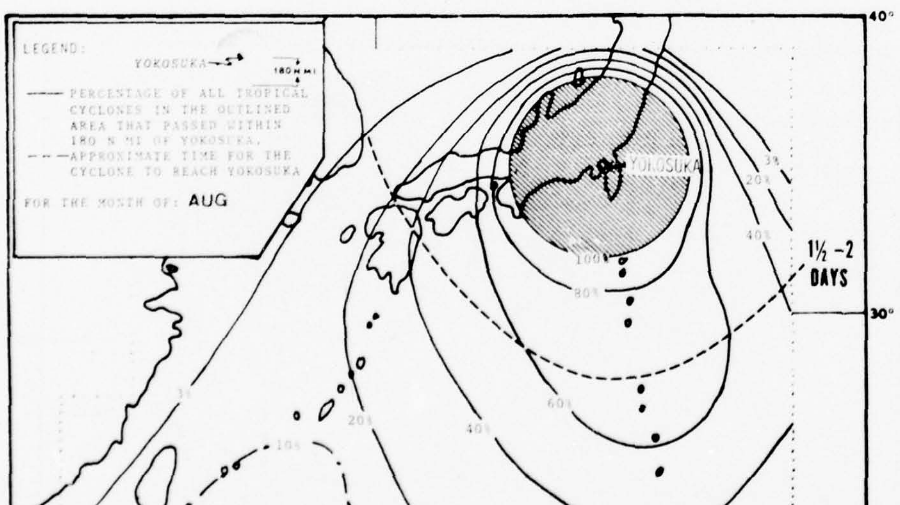

Figure V-8. Probability that a tropical cyclone will pass within 180 n mi of Yokosuka in August. (Based on data from 1947-1973.)

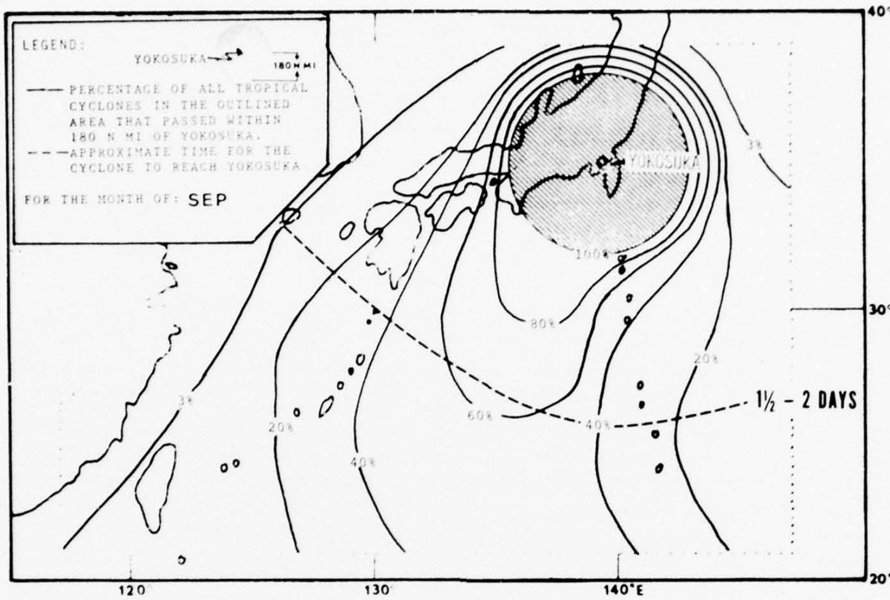

Figure V-9. Probability that a tropical cyclone will pass within 180 n mi of Yokosuka in September. (Based on data from 1947-1973.)

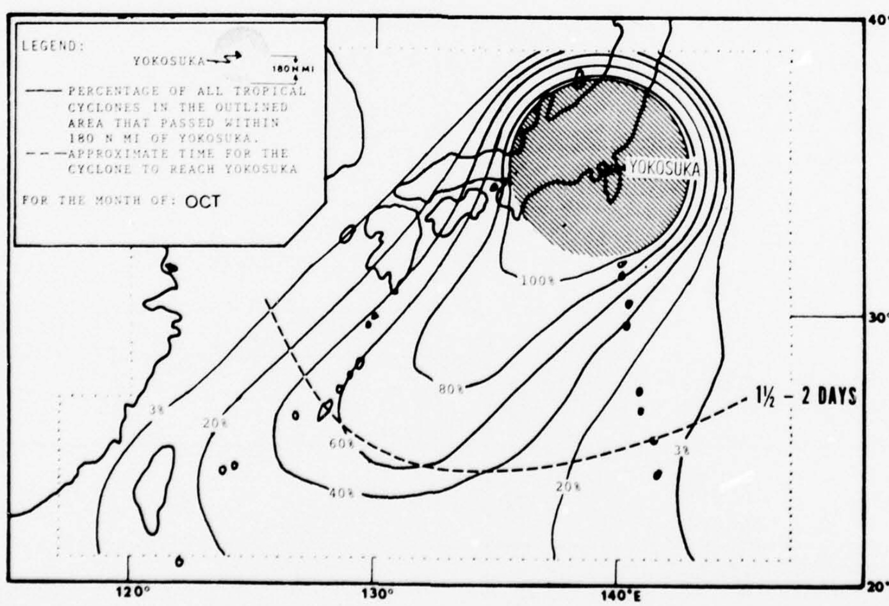

Figure V-10. Probability that a tropical cyclone will pass within 180 n mi of Yokosuka in October. (Based on data from 1947-1973.)

For Figures V-6 through V-10, the speed range was arrived at by considering that as tropical cyclones recurve their forward speed characteristically, but not always, slows to about 10 kt during the recurvature period. It should be expected that the system will subsequently accelerate rapidly toward the north or northeast. Speeds of 20 to 30 kt are common and speeds as great as 50 kt have been observed. Table V-1 presents information from which the approximate time in days for a tropical cyclone to reach Yokosuka was computed.

Table V-1. Listing of average climatological speeds of tropical cyclones by 5-degree latitude bands for the months of June-October.

Latitude Band (°N)	Average Forward Speed of Movement (kt)					Average of the 5 Months (kt)
	Jun	Jul	Aug	Sep	Oct	
30-35N	23 kt	15	13	20	28	19.8 kt
25-30	17	12	11	14	21	15.0
20-25	13	10	11	11	13	11.6
15-20	10	10	10	11	12	10.6

2.3.2 Wind And Topographical Effects

In the 5 months June-October for the 22 years of 1952-1973, a total of 64 tropical cyclones passed within 180 n mi of Yokosuka, or about 3 per year. Table V-2 groups the 64 tropical cyclones by strong (≥22 kt) and gale force (≥34 kt) wind intensities they produced at Yokosuka.[4] Tropical cyclone activity within 180 n mi of Yokosuka is maximum during the months of August and September and these individual monthly values are also shown.

Table V-2. Extent to which tropical cyclones affected Yokosuka during the period 1952-1973, June-October and for the individual months of August and September.

	Jun-Oct	Aug	Sep
Number of tropical cyclones that passed within 180 n mi of Yokosuka	64	22	19
Number of tropical cyclones resulting in strong (≥22 kt) winds at Yokosuka	47 (73%)	14 (64%)	15 (79%)
Number of tropical cyclones resulting in gale force (≥34 kt) winds at Yokosuka	20 (31%)	5 (23%)	11 (58%)

[4] Based on hourly data provided by Naval Weather Service Detachment, Asheville, N.C.

It can be discerned from Table V-2 that only 20 (31%) of the total 64 tropical cyclones for the period June-October (1952-1973) resulted in winds of 34 kt or greater at Yokosuka. However, note that of the 19 tropical cyclones in September, 11 (58%) of these resulted in winds of 34 kt or greater.

Figures V-11 and V-12 show the tracks of the 20 tropical cyclones that resulted in gale force winds or greater at Yokosuka for the period June-October, 1952-1973. Figure V-12 isolates the 11 tracks of September in order to show that most of these passed west of Yokosuka and initially struck Japan on the south coast of Honshu. Note in Figures V-11 and V-12 that recurvature generally occurs further south for the September and October tropical cyclones than do the July and August systems. Also, in Figure V-11 note the track of the tropical cyclone which is headed in an easterly direction and then looped back toward Honshu again!

When the tracks in Figures V-11 and V-12 are compared with all the tracks for the same monthly period in Appendix 1-A it can be seen that, while tropical cyclones have approached Yokosuka from virtually all southerly directions, the vast majority approach along a threat axis that is oriented generally southeast to west-southwest from Yokosuka. This threat axis is evident in Figures V-6 to V-10 by the "percent threat" lines.

The observation station for the Naval Weather Service Facility (NWSF), Yokosuka is located on top of a 175 ft hill at FLEACTS Yokosuka, and the wind instrument is another 55 feet above the station; the observed wind velocity is about 10 kt greater than that observed in the harbor, but otherwise is representative. In the period 1953-1973, the highest recorded wind (gust) in Yokosuka was 96 kt. The southerly gust of 96 kt was attributed to Typhoon Ida which passed about 20 n mi to the northwest of Yokosuka on 26 September 1958.

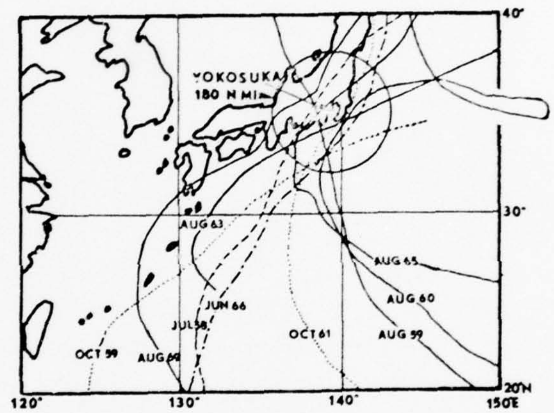

Figure V-11. Tracks of 9 tropical cyclones resulting in winds ≥34 kt at Yokosuka for the months June-August and October. (Based on data from 1952-1973.)

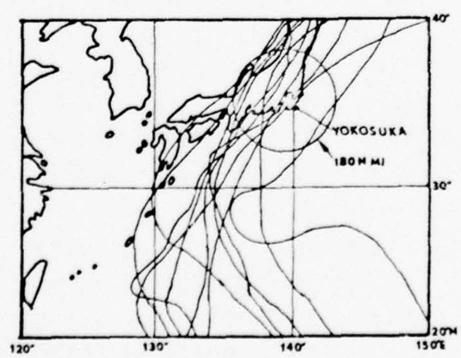

Figure V-12. Tracks of 11 tropical cyclones resulting in winds ≥34 kt at Yokosuka for the month of September. (Based on data from 1952-1973.)

YOKOSUKA

Winds in the harbor during the passage of a severe tropical cyclone are greatly influenced by the surrounding topography and the extent of this influence is dictated by the direction of approach of the storm and the passage relative to Yokosuka. From an analysis of the tropical cyclone tracks in Figures V-11 and V-12, it is apparent that tropical cyclones can pass to the east or to the west of Yokosuka and result in gale force winds or greater at Yokosuka. The basic difference between the two passages is the direction of the resultant wind on the harbor. If the tropical cyclone passes to the west of Yokosuka, the winds will generally be from the south. For a passage to the west, the storm must necessarily cross the mountain ranges of Honshu (see Figure V-2). An example of this was Typhoon Nancy (September, 1961) which had a closest point of approach (CPA) of 140 n mi west-northwest of Yokosuka. Nancy pounded the harbor with gusts of 71 kt from the south-southwest and a sustained wind of about 50 kt for a 4-hour period.

If the tropical cyclone passes to the east of Yokosuka, the path will be over water and the winds will be generally northerly. An example of this was Typhoon Violet (Oct, 1961) which had a CPA of 30 n mi to the southeast of Yokosuka. As a result of Violet, the harbor experienced gusts of 74 kt from the north-northeast.

Units of the SEVENTH Fleet in port Yokosuka during the threatening times of Nancy and Violet reported negligible damage.

The beginning and end point of the arrows in Figure V-13(A) give the positions of tropical cyclone centers when winds $\geq$22 kt occurred at Yokosuka for 47 of the 64 tropical cyclones (June-December, 1952-1973) that passed within 180 n mi of Yokosuka. Seventeen of these 64 tropical cyclones did not result in winds $\geq$22 kt. Similarly, Figure V-13(B) shows the positions of tropical cyclone centers when winds $\geq$34 kt occurred at Yokosuka.

In Figure V-13(A), it appears that 22-kt winds or greater do not generally occur until the tropical cyclone center has reached 32°N. The tracks of the 64 tropical cyclones indicate that 47% passed to the west of Yokosuka and the remainder passed to the east. A high concentration of line segments is found in the northeast and southeast quadrants, relative to Yokosuka, implying that centers located in this region tend to cause $\geq$22 kt winds in more instances than centers located in other quadrants. The relative flat regions to the north and northeast of Yokosuka account for this. Several of the centers over 600 n mi from Yokosuka continued to generate 22-kt or greater winds at Yokosuka.

Note in Figure V-13(B) that 12 (60%) of the 20 tracks associated with the positions of tropical cyclone centers passed to the west of Yokosuka. The observed gale force wind velocities in Yokosuka resulting from these tropical cyclones generally first exceeded 33 kt when the center was to the north and east of Yokosuka. A number of times tropical cyclone centers were nearly 300 n mi to the north and east, yet gale force winds were observed at Yokosuka.

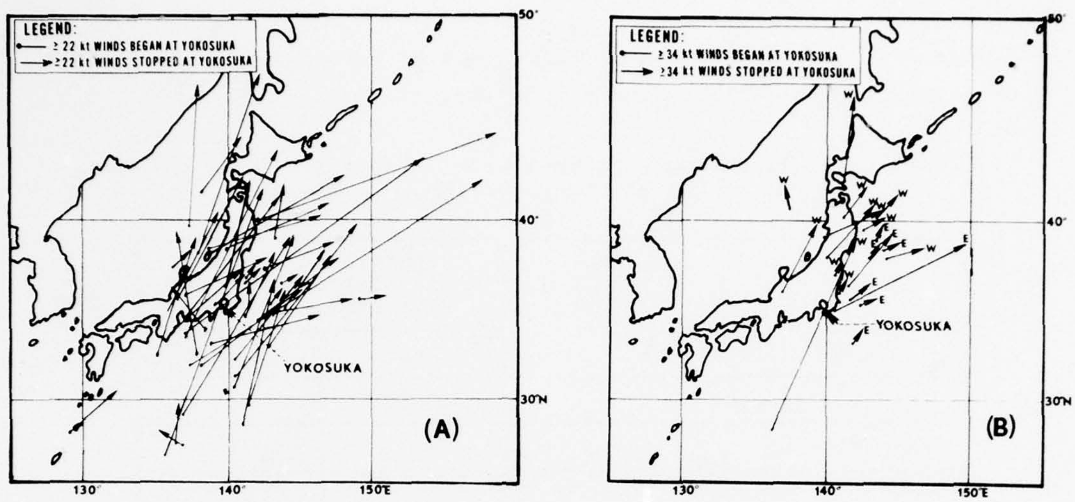

Figure V-13. Positions of (A) 47 tropical cyclone centers when 22-kt winds and (B) 20 tropical cyclone centers when 34-kt winds first and last occurred at Yokosuka (based on hourly wind data for the months of June-October for the years 1952-1973. Note: The letter at the arrowheads in (B) shows the direction of the closest point of approach which the associated tropical cyclone had with respect to Yokosuka.

2.3.3 Wave Action

The port of Yokosuka experiences very little wave action as the result of a typhoon transiting the vicinity. The amount of wave action will vary according to whether the typhoon passes to the west or to the east of the port with the resulting southerly or northerly winds, respectively. The surrounding land masses and the breakwater located near the entrance to Yokosuka Harbor are major factors in limiting the wave action in the port of Yokosuka. Wave action will be greater for a northerly wind (typhoon passage to the east). The port of Yokosuka opens onto Tokyo Bay in a north-northeast direction for a distance of about 25 n mi (see Figure V-1). Prior to arriving at Yokosuka any wind-generated waves from a northerly direction must traverse various natural and man-made obstacles, hence much of the energy contained in these waves is depleted.

An estimate of the maximum wave height that may be encountered for typhoon force winds in the region about Yokosuka and Tokyo Bay is summarized in Table V-3. The major factors considered in this listing were the direction of tropical cyclone passage relative to Yokosuka, the direction and velocity of the resultant typhoon force winds, the length of fetch, a duration greater than 1 hour but less than 5 hours, and the location of obstacles in the path of the progressing waves. There is no single theoretical development for determining

the actual growth of waves generated by winds over relatively shallow water (U.S. Army Coastal Engineering Research Center, 1973).

Table V-3. Approximate maximum wave heights (in feet) about the Yokosuka region and Tokyo Bay.

Wave Height (ft) in the Vicinity of	Direction of Passage of Tropical Cyclone Relative to Yokosuka	
	East	West
Port of Yokosuka	6 ft	3 ft
Yokosuka Bay	9	5
Tokyo Bay (about 10 n mi north-northeast of Yokosuka)	12	11

2.3.4 Storm Surge

Storm surge may be defined as an abnormal rise of the sea along a shore as the result of the winds of a storm and the pressure drop. The piling up of water on a coast ahead of a tropical storm or typhoon is more apparent in the dangerous semicircle, the region of most intense winds. The port of Yokosuka will be placed in the dangerous semicircle, when a typhoon passes to the west of the area.

The storm surges are more pronounced along the south coast of the Japanese Islands to the west of Tokyo Bay. Tokyo Bay opens onto the south coast of Honshu. The surge forms to a large extent after entering the inland bays since the width of the continental shelf is generally narrow along the Japanese coast. Most of the surge occurs, therefore, at the inshore side of these bays, not along the open coasts nor near the mouth of the bays. During the period 1900 to 1973, peak surges of 7.6 ft (Oct, 1919) and 7.3 ft (Sept, 1938) were observed at the inshore side of Tokyo Bay. They were the result of southerly winds caused by typhoons passing generally to the west of Tokyo Bay.

Due to its sheltered position within Tokyo Bay and its location near the entrance, Yokosuka experiences little storm surge. Conversations with civilian employees of the Port Services Office, Yokosuka, indicate that storm surges of about 3 ft have been felt within the harbor but have not been a problem. Surges of this magnitude coupled with the normal tide range of 4-5 ft for the months of June-October do not present any unusual difficulty to vessels, if mooring lines are tended.

For a more detailed discussion on the effects of tropical cyclones on Yokosuka, see Graff (1975).

2.4 THE DECISION TO EVADE OR REMAIN IN PORT

2.4.1 General

The responsibility for overall coordination of action to be taken by Naval activities in the Yokosuka area has been assigned to Commander, Fleet Activities, Yokosuka. The Naval Weather Service Facility, Yokosuka issues the local wind warnings. The established procedures in the event hazardous weather is expected is contained in SOPA (ADMIN) YOKOSUKA INSTRUCTION 5000.1 series.

Wind from any direction with expected sustained speeds of 48 kt or gusts in excess of 55 kt is sufficient to set storm conditions as directed by SOPA. Typhoon conditions will be set as above for an approaching typhoon, i.e., expected sustained winds of 64 kt or greater. The same precautions taken for a typhoon will also be taken for any storm.

For general information on tropical cyclone warnings, refer to paragraphs 6 and 7 of Chapter I.

2.4.2 Evasion Rationale

Of utmost importance is that the commander recognize the inherent dangers that exist when exposed to the possibility of hazardous weather. By proper utilization of the meteorological products, especially the FWC/JTWC, Guam Tropical Cyclone Warnings, and a basic understanding of weather, the commander will be able to act in the best interest of his unit and to complete his mission when the unfavorable weather subsides. The following time table (in conjunction with Figures V-14 to V-18 corresponding to the five months June-October) has been set up to aid in these actions. The orientation of the threat axis in Figures V-14 to V-18 was derived by considering the general direction from which the tropical cyclones approached to within 180 n mi of Yokosuka. The time in days to reach Yokosuka was based on typical speeds of tropical cyclones affecting Yokosuka.

I. An existing tropical cyclone moves into or development takes place in Area A with long range forecast movement toward Yokosuka (recall that about 40% of all tropical storms and typhoons recurve):

   a. Review material condition of ship.

   b. Reconsider any maintenance that would render the ship incapable of riding out a storm or typhoon with the electrical load on ship's power, or would render the ship incapable of getting underway, if need be, within 48 hours.

   c. Plot FWC/JTWC, Guam warnings if issued and construct the danger area. Reconstruct the danger area for each new warning.

II. Tropical cyclone enters Area B with forecast movement toward Yokosuka (recall that prior to recurvature tropical cyclones tend to slow in their forward motion and after recurvature accelerate rapidly):

a. Reconsider any maintenance that would render the ship incapable of shifting to a new berth assignment, anchorage or buoy or otherwise getting underway, prior to the commencement of strong winds within the harbor.

b. Anticipate Storm/Typhoon Condition III.

III. Tropical cyclone has entered Area C and is moving toward the Yokosuka area:

a. Anticipate Storm/Typhoon Conditions II and I.

A high velocity wind is the single most important factor to be considered. The effects of wave action and storm surge are negligible in the port of Yokosuka.

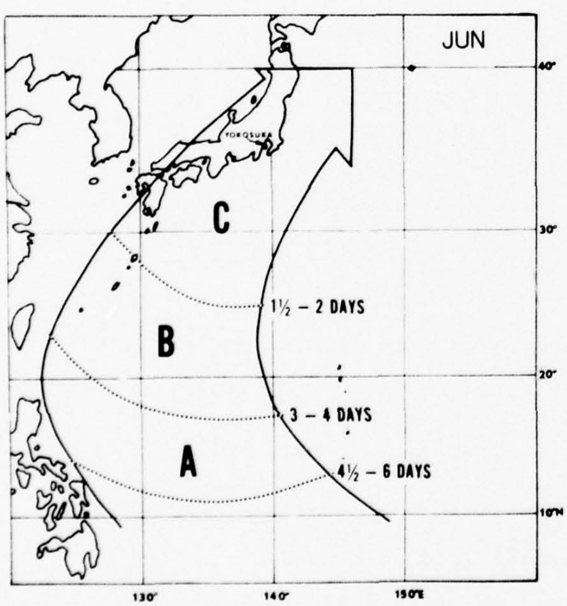

Figure V-14. Tropical cyclone threat axis for Yokosuka for the month of June.

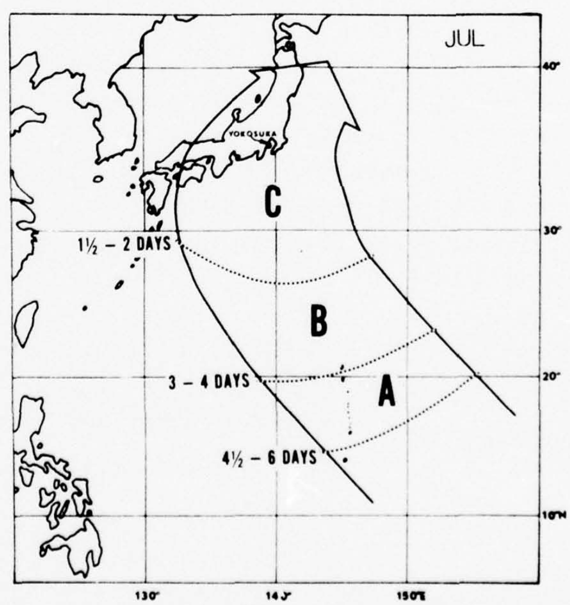

Figure V-15. Tropical cyclone threat axis for Yokosuka for the month of July.

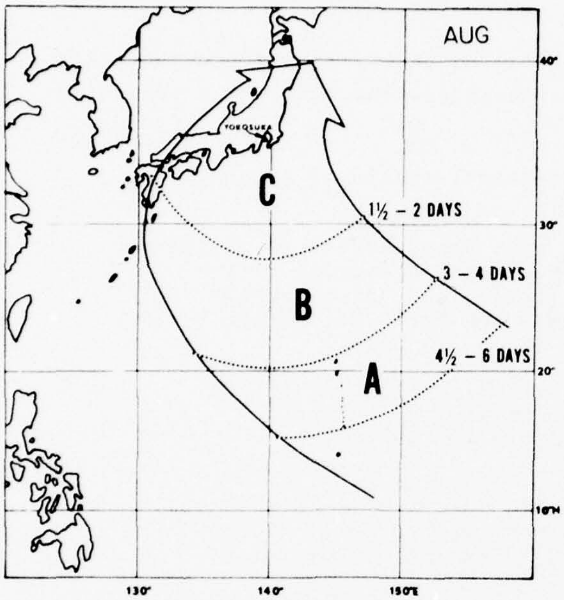

Figure V-16. Tropical cyclone threat axis for Yokosuka for the month of August.

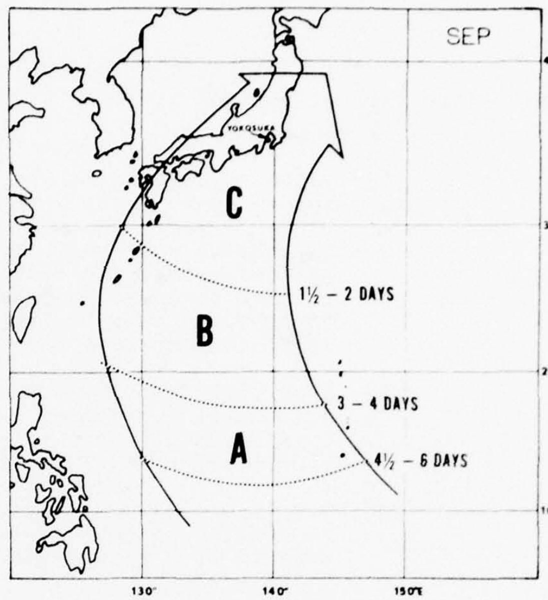

Figure V-17. Tropical cyclone threat axis for Yokosuka for the month of September.

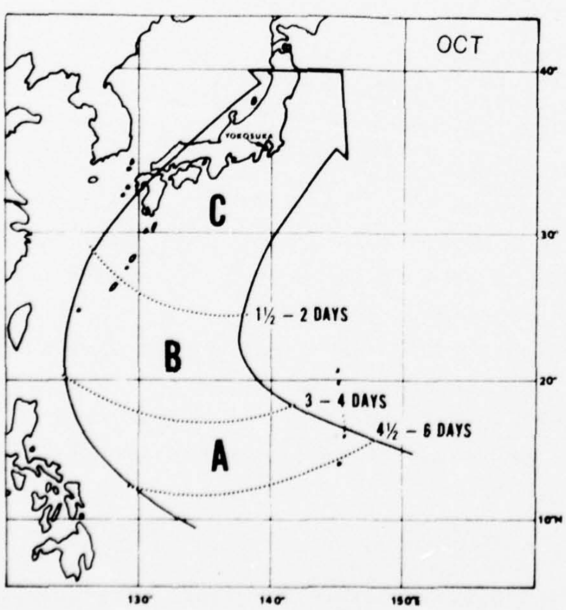

Figure V-18. Tropical cyclone threat axis for Yokosuka for the month of October.

2.4.3 Remaining In Port

Remaining in port is, in almost all instances, the recommended course of action when a tropical storm or typhoon threatens Yokosuka. The following items must be considered:

(1) Berth reassignments, if necessary, should be accomplished before 20-kt winds begin.

(2) Ships with extremely large sail areas should be assigned preferred berthing depending on the direction of the closest point of approach (CPA); i.e., if a typhoon is forecast to pass to the east, use berth 8,[5] and use berth 12 if the forecast passage is to the west.

(3) Some flooding, caused by heavy precipitation, of the U.S. Fleet Activities land complex may occur; therefore, all ships should provide their own electrical power.

(4) A ship with a large sail area, for example an LPD that is berthed at the floating pier (berth 10 or 11) may want to have a tug standing by during the period of highest winds.

(5) Ships should put out extra line and wire as deemed necessary and should be ready to tend mooring lines.

(6) Although the rated holding strengths of the mooring buoys inside the confines of the port are good, they are not the preferred location to be when high velocity winds are expected. Their orientation with respect to the surrounding land masses does not give them the same protection as do the pierside berths.

(7) The anchorages within Yokosuka Bay have mud and sand bottoms, hence their holding quality would be poor in the event of typhoon intensity winds. In addition, anchorages and mooring buoys in Yokosuka Bay are unprotected from northerly winds and relatively unprotected from southerly winds.

Where there are crowded conditions within the port of Yokosuka and thus limited pierside facilities, this may be an instance when a ship would elect to evade the typhoon at sea or anchor in Tokyo Bay.

Ships of the JMSDF consider their port of Nagura (see Figure V-1) a good typhoon haven if a ship is pierside and, generally, do not sortie to avoid a typhoon. However, ships anchored in the vicinity of Nagura or moored to a buoy usually get underway and proceed to anchorages in various parts of Tokyo Bay.

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[5] See SOPA (ADMIN) YOKOSUKA INSTRUCTION 5000.1, Harbor Movements - Entering and Leaving Harbor.

2.4.4 Evasion In Tokyo Bay

JMSDF ships have, in the past, anchored in Tateyama Bay for typhoon passage to the east of Tokyo Bay. They also make use of Kisarazu Harbor.

Merchant vessels have at times, depending on the direction of the tropical storm or typhoon CPA, anchored in the following areas:[6]

(1) Tropical cyclone passage to the east or south of Tokyo Bay - anchor in Chiba Harbor or Kisarazu Harbor.

(2) Tropical cyclone passage to the west or north of Tokyo Bay - anchor in Kaneda Bay.

Vessels carrying a dangerous cargo must anchor as directed by the Japanese Maritime Safety Office. Ships requiring a pilot to transit the Uraga Suido Traffic Route may be unable to secure pilot services if winds are greater than about 35 kt because pilots embark and debark from small motor launches.

2.4.5 Evasion At Sea

The widely held doctrine of evasion at sea rather than remaining in port for the single purpose of minimizing typhoon-related damage is not generally recommended when in port at Yokosuka. However, if putting to sea is desirous each tropical storm or typhoon must be considered as differing from those preceding it. The accompanying synoptic situation must be fully understood. To establish one technique or rule to avoid the danger area is not practical. The Japanese say that, "the only solution is that there is no one solution."

In general, the effects of wave/swell generated by a tropical cyclone generally begin to be felt in the vicinity of Kannon Saki and may reduce the speed of advance (SOA) thereby increasing the time required to reach the open sea (see Figure V-1). If a ship is caught in the wave/swell pattern ahead of a tropical cyclone, in particular an intense tropical storm or typhoon, the SOA may be reduced to the point that the ship will be unable to maneuver to clear the danger area (see Figure I-4). If the typhoon is forecast to follow a recurving track, with a CPA to the east of Yokosuka, then a course downsea/downwind, in the left or navigable semicircle may be advisable.

Any course to the north along the east coast of Honshu is considered unwise. The possibility of being overrun exists if the storm accelerates and/or turns suddenly to the north. The average speed of advance in the higher latitudes (30-40°N) of tropical cyclones is about 25 kt; however, they have been tracked as fast as 50 kt. Typhoon wind intensities tend to decrease as the system moves into the northern latitudes but nevertheless can be quite destructive.

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[6] See Defense Mapping Agency Hydrographic Center charts N.O. 97151 and N.O. 97143.

3. NUMAZU OPERATING AREA

SUMMARY

The conclusion reached in this study is that Suruga Bay, including the Numazu Operating Area should not be considered a "safe" typhoon haven for ships operating in the area or transiting the south central coast of Honshu. The primary factors in reaching this conclusion are:

(1) The openness of the bay to the effects of the ocean -- especially in the southwestern quadrant.

(2) The lack of any suitable sheltered area for a ship to lie to or anchor in.

(3) Wind and swell wave action can be as devastating in the Suruga Bay area as on the open ocean if these effects are being felt from the south-southwest. (A southwesterly wind gust of 97 kt was recorded at Numazu on 25 September 1966 as Typhoon Ida passed 30 n mi to the west. Winds in excess of 34 kt existed for 5 hours.)

Some protection from northeasterly winds (associated with a tropical cyclone passing to the east) may be found by keeping close to the Izu Peninsula (eastern) side of the bay. This should reduce the effects of the wind and wind generated waves because of the shorter fetch the winds would blow over. In spite of the deep water in Suruga Bay, caution should be exercised when operating close to land as visibility may be reduced and radar reception hindered by the effects of a tropical cyclone passing close by. Also the confused sea state with accompanying wind may set up unpredictable local currents.

Additionally, it has been concluded that surf conditions in the Numazu Operating Area may be unsafe for small craft operation for a number of days after a tropical cyclone passes CPA because of the slow decay rate of swells associated with such a storm. This conclusion can also be applied to tropical cyclones, especially typhoons, that pass well to the south of the 180 n mi threat circle used in this study.

To avoid the effects of tropical cyclones that pose a threat to the Numazu Operating Area, evasion to the Yokosuka/Tokyo Bay area is highly recommended.

3.1 LOCATION AND TOPOGRAPHY

The terrain around Suruga Bay is generally rugged and mountainous. The dominant topographic feature in the area is Fujiyama (12,395 ft), the highest mountain in Japan. This extinct volcano rises from the northern shore of the bay to its peak, 12 n mi away. Along the eastern and western coasts, the mountains rise abruptly to heights in excess of 4000 ft and 6000 ft, respectively.

These ridges lie generally in a north-south orientation with a "saddle" between them and Fujiyama. Figure V-2 (Yokosuka section) shows the topographic features of this region.

The Numazu Operating Area takes its name from the city of Numazu, which is located at 35°05'N, 138°52'E at the northwestern side of the Izu Peninsula on the northeast shore of Suruga Bay. The harbors of Shimizu and Tagonoura are also located, respectively, on the western and northern shore of Suruga Bay. Figure V-19 locates some pertinent features. Suruga Bay penetrates the southern coast of Honshu in a north-northeasterly direction for a distance of approximately 35 n mi. Numerous ships of various sizes transit the bay enroute to the harbors mentioned.[7]

Suruga Bay itself is characterized by extreme depths. At its entrance, the depth is in excess of 2500 m. An exception is in the south central region of the bay where the bottom rises up to within 30 m of the surface. Along the northern shore the bottom drops off to over 200 m within a mile of the coast.

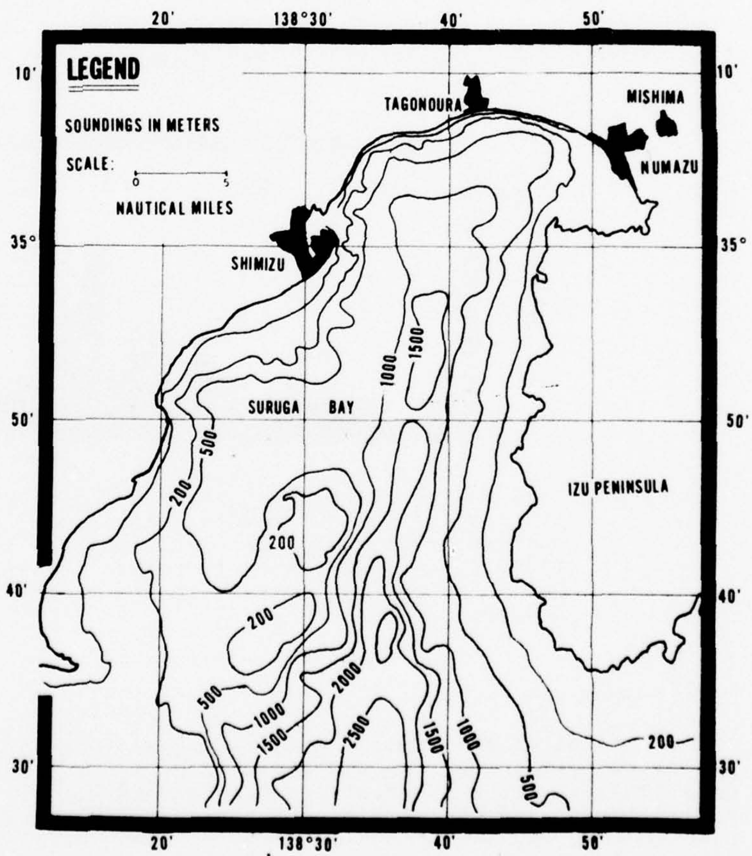

Figure V-19. Geographical depiction of Suruga Bay featuring the bathymetry of the Bay.

[7]Shimizu is a major container ship port for central Honshu; Tagonoura is a small exporting industrial city; and Numazu is a local port for small (less than 500 tons) fishing and rock gathering boats.

3.2 TROPICAL CYCLONES AFFECTING THE NUMAZU OPERATING AREA

3.2.1 Tropical Cyclone Climatology for Numazu

Tropical cyclones which affect the Numazu Operating Area generally form in an area bounded by the latitudes 5°N and 30°N and the longitudes 120°E and 165°E. The latitudinal boundaries shift poleward during the summer months and then equatorward in winter in response to the seasonal location of the southern boundary of the prevailing easterlies.

In the genesis area mentioned above, typhoons have occurred in all months but, with rare exceptions, those affecting the main Japanese Islands are confined to the period May to November. Late summer and early autumn are the likeliest seasons. Size and intensity of the storms vary widely. The majority of those that pose a "threat" to the area (any tropical cyclone approaching within 180 n mi of Numazu is defined as a "threat" for the purpose of this study) occur during the months June-October. Figure V-20 gives the frequency distribution of threat occurrences by 5-day periods. This summary of 84 tropical cyclones is based on data for the 28-year period, June-October 1947-1974. Note that the maximum number occur during August and September.[8]

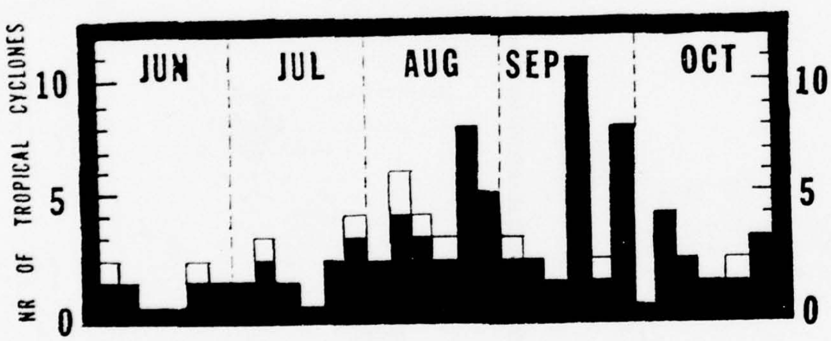

Figure V-20. Frequency of tropical cyclones that passed within 180 n mi of the Numazu Operating Area. Subtotals are based on 5-day periods for tropical cyclones that occurred during 1947-1974. Shaded area indicates recurving tropical cyclones per 5-day period (that is, had a northeasterly direction of movement at CPA).

[8]A total of 89 tropical cyclones passed within 180 n mi of the Numazu Operating Area during the May-November period for the years 1947-1974. Eighty-four (94%) of these tropical cyclones passed within 180 n mi during the 5 months, June-October, and the remaining 5 passed in the months May and November.

Figure V-21 displays the "threat" of tropical cyclones according to the octant from which they approached the 180 n mi radius threat area. The circled numbers indicate the total that approached from an individual octant. The figure count for an octant of approach includes both recurving and non-recurving tropical cyclones. (See Chapter I, paragraph 3 for description of recurving tropical cyclones.) The adjacent numbers express this as a percentage. It is evident that a majority of these approach from the southwestern quadrant. A more detailed inspection of the sample of 84 tracks reveals that 11 (13%) did not recurve before passing the closest point of approach (CPA) to the Numazu Operating Area.

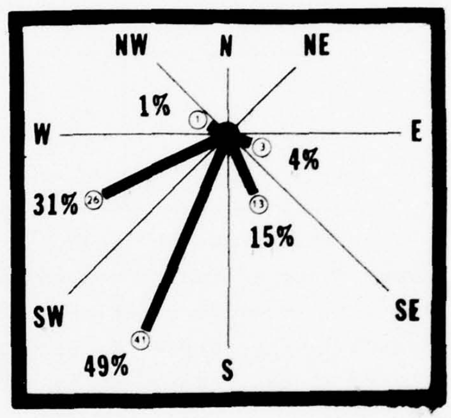

Figure V-21. Directions from which tropical cyclones entered threat area during the period 1947-1974. Numbers circled indicate the number of tropical cyclones that entered from each octant. This is expressed as a percentage adjacent to the circled number.

Table V-4 indicates that of the 84 tropical cyclones that posed a "threat" to the Numazu Operating Area during the years 1947-1974, 46% passed to the east of Numazu, 42% passed to the west and 12% passed in the immediate vicinity (within 20 n mi) of the area. The apparent majority of the "threat" tropical cyclones passing to the west or in the immediate vicinity implies that the Numazu Operating Area is placed quite often in the right or "dangerous" semicircle where the winds and seas are more intense.

Table V-4. "Threat" tropical cyclone passage relative to Numazu (1947-1974).

TRACK RELATIVE TO NUMAZU	JUN	JUL	AUG	SEP	OCT	TOTAL
Passed east of Numazu	3	3	13	12	8	39
Passed west of Numazu	2	7	12	11	3	35
Passed in the immediate vicinity of Numazu	1	1	3	4	1	10

NUMAZU

Figures V-22 through V-26 represent an analysis of the estimated "threat" probability for any tropical cyclone as it approaches the Numazu Operating Area. The solid lines represent the probability of a system within an isoline coming within 180 n mi of the Numazu Operating Area. The dashed lines represent the approximate time in days for a system to reach Numazu based on typical speeds of movement of tropical cyclones affecting Numazu (Table V-5). For example, in Figure V-22, a tropical cyclone located at 27°N, 140°E has a 60% probability of passing within 180 n mi of the Numazu Operating Area and it will reach Numazu in about one day.

Table V-5. Average tropical cyclone speed of movement (kt) per 5-degree latitude band for tropical cyclones affecting the Numazu Operating Area for June-October.

LATITUDE BAND	JUN	JUL	AUG	SEP	OCT	AVERAGE
30 - 35 N	23	15	13	20	28	19.8
25 - 30	17	12	11	14	21	15.0
20 - 25	13	10	11	11	13	11.6
15 - 20	10	10	10	11	12	10.6

The speeds in Table V-5 were derived by considering that as tropical cyclones recurve, their forward speed characteristically, but not always, slows during the recurvature period. It should be expected that the system will subsequently accelerate rapidly toward the north or northeast. Speeds of 20 to 30 kt are common and speeds as great as 50 kt have been observed.

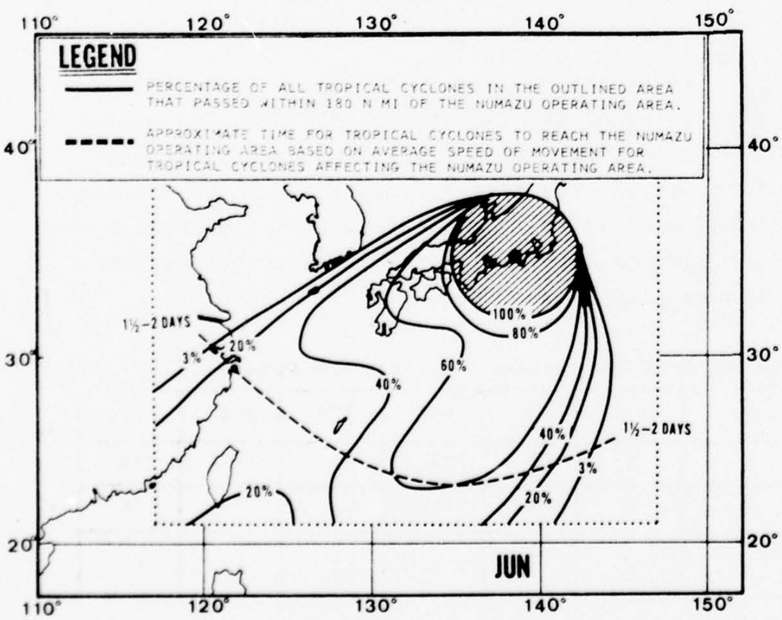

Figure V-22. Probability that a tropical cyclone will pass within 180 n mi of Numazu (shaded area) in June. (Based on data from 1947-1974.)

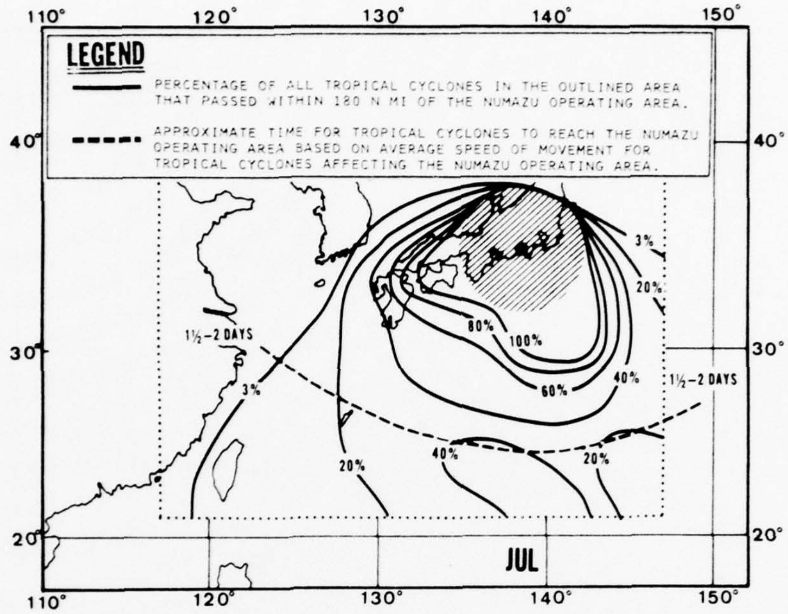

Figure V-23. Probability that a tropical cyclone will pass within 180 n mi of Numazu (shaded area) in July. (Based on data from 1947-1974.)

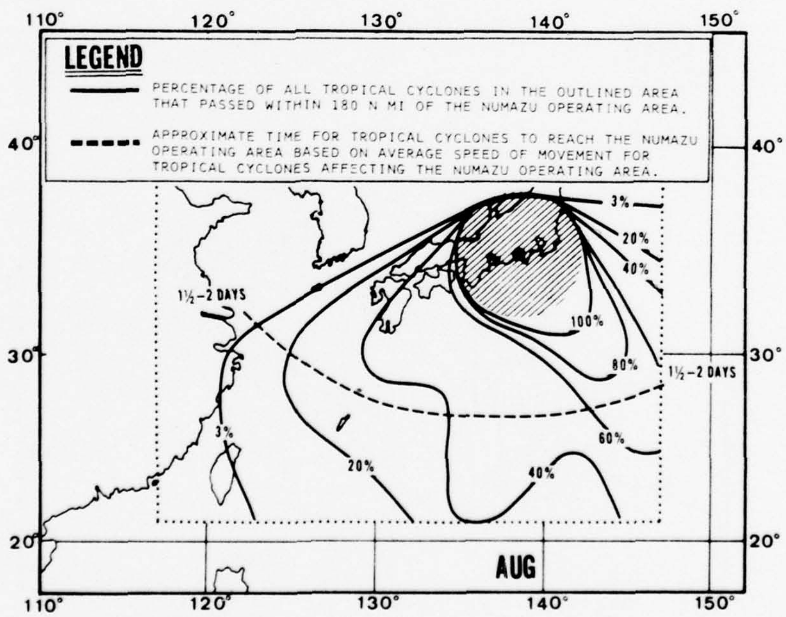

Figure V-24. Probability that a tropical cyclone will pass within 180 n mi of Numazu (shaded area) in August. (Based on data from 1947-1974.)

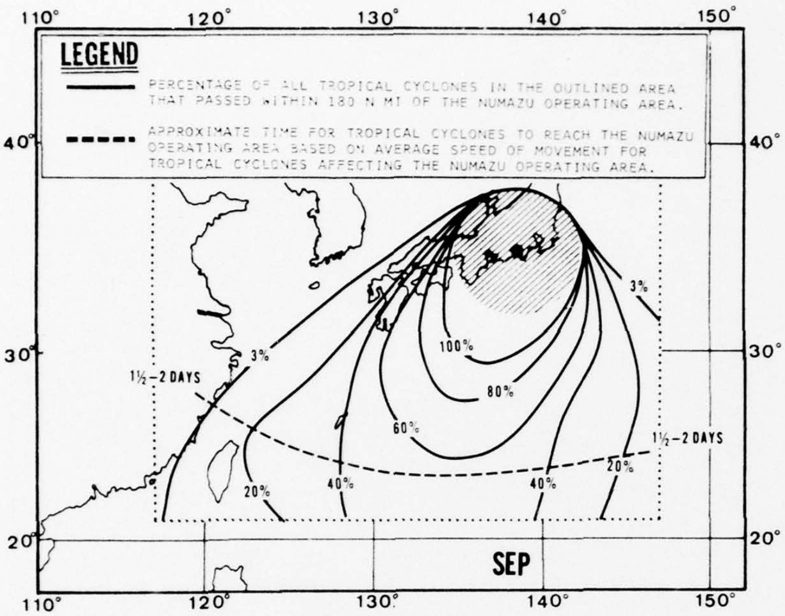

Figure V-25. Probability that a tropical cyclone will pass within 180 n mi of Numazu (shaded area) in September. (Based on data from 1947-1974.)

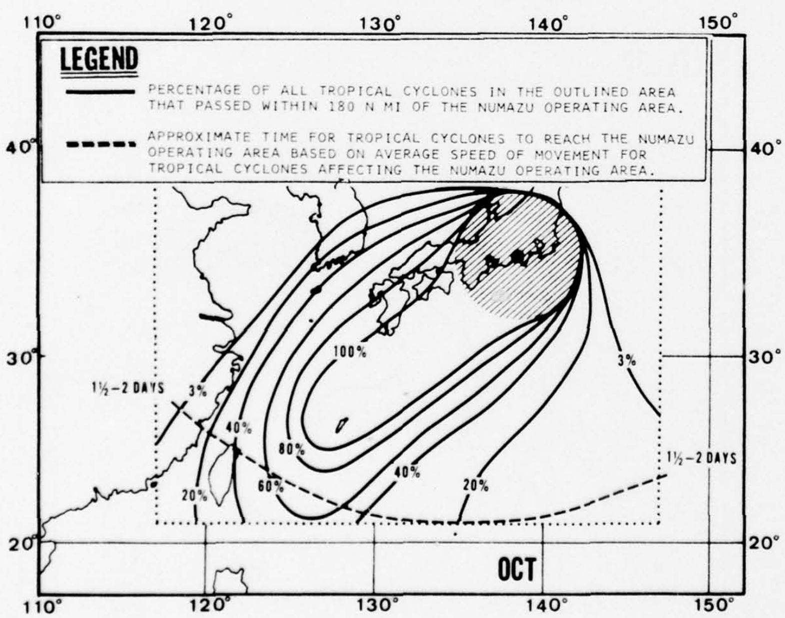

Figure V-26. Probability that a tropical cyclone will pass within 180 n mi of Numazu (shaded area) in October. (Based on data from 1947-1974.)

3.2.2 Wind And Topographical Effects

A total of 50 tropical cyclones passed within 180 n mi of the Numazu Operating Area in the 19-year period 1956-1974 during the months June-October, or about 2.6 per year.[9] Table V-6 groups the 50 tropical cyclones by strong (≥22 kt) and gale force (≥34 kt) wind intensities (based on hourly wind data) that they produced at Mishima.[10] Tropical cyclone activity within 180 n mi of the Numazu Operating Area is at a maximum during the months of August and September and these individual monthly values are also shown.

Table V-6. Extent to which tropical cyclones affected the Numazu Operating Area during the period June-October, 1956-1974 and for the individual months of August and September.

	JUN-OCT	AUG	SEP
Number of tropical cyclones that passed within 180 n mi of the Numazu Operating Area	50	20	16
Number of tropical cyclones resulting in strong (≥22 kt) winds in the Numazu Operating Area	39 (78%)	14 (70%)	15 (94%)
Number of tropical cyclones resulting in gale force (≥34 kt) winds in the Numazu Operating Area	25 (50%)	10 (50%)	10 (63%)

It can be discerned from Table V-6 that 25 (50%) of the total 50 tropical cyclones for the period June-October (1947-1974) resulted in winds of 34 kt or greater at Mishima. However, note that of the 16 tropical cyclones in September, 10 (63%) of these resulted in winds of 34 kt or greater.

The observation station at Mishima is located approximately 3 n mi northeast of the city of Numazu. The wind instrument is located on top of the station in a residential section of the city. There is no appreciable difference in the elevaticn of the station and that of Numazu, both being located in a flat coastal plain lying between the mountainous ridge running south into the Izu Peninsula and Fujiyama to the northwest. The observed wind is fairly representative of that at the Numazu Harbor where the observation station had been

[9] From Chin (1972) for years 1956-1970 and from Annual Typhoon Reports for years 1971-1974 (FWC/JTWC, 1971-1974).

[10] Data provided by the Japanese Meteorological Agency weather station located at Mishima, 3 n mi inland from the Numazu Harbor (see Figure V-19).

previously located. However, during the period 1964-1973, the highest recorded wind gust in Numazu was 97 kt on 25 September 1966 while at Mishima the wind gust was recorded at 82 kt (also the highest recorded during the period). This southeasterly gust was attributed to Typhoon Ida which passed 30 n mi to the west of Numazu on 25 September 1966. During this particular typhoon, sustained winds were recorded in excess of 34 kt for 5 hours.

Winds in Suruga Bay are greatly influenced by the surrounding topography and geographical features of the bay itself. The extent of this influence is dictated by the direction of approach of the storm and the passage relative to the Numazu Operating Area. From an analysis of the tropical cyclone tracks that affected Numazu, it is apparent that tropical cyclones that result in gale force winds or greater at Mishima can pass to the east or west of Mishima or in some instances the center of the storm passes over the immediate area. The basic difference between the passages is the direction of the resulting winds in the area.

If the tropical cyclone passes to the west of the Numazu Operating Area, the winds will be predominantly from the southwest. For a passage to the west, the storm must necessarily cross the mountain ranges of Honshu. An example of this was Typhoon Vera (September 1959) which had a CPA of 110 n mi to the northwest of Mishima. The typhoon pounded the area with gusts of 68 kt from the southwest and sustained gale force winds for a 7-hour period.

If the tropical cyclone passes to the east of Mishima, the path will generally be over water and the winds will be primarily northeasterly. An example of this was Typhoon Ida (September 1958) which had a CPA of 30 n mi to the southeast of Mishima. As a result, the area experienced gusts of 64 kt from the north-northeast.

Occasionally, a tropical cyclone will pass in the vicinity of Suruga Bay. In the 28-year period (1947-1974), ten tropical cyclones tracked in such a manner with 7 of them bringing gale force winds to the area. Under such circumstances there is no discernable pattern of a prevailing direction from which the strongest winds originate. Nor is the proximity of a storm's center indicative of force. Of the 10 tropical cyclones tracked, the maximum wind gust recorded ranged from 20 kt to 85 kt.

Figure V-27 shows the position of "threat" tropical cyclone centers when strong winds ($\geq$22 kt) were first and last recorded at Mishima. A number of storms gave Mishima $\geq$22 kt winds when they were 300 n mi from the city with a predominant number of occurrences to the south and east of the Numazu Operating Area. Note also that strong winds were still being generated by a few storms when the storm centers were as far north as the island of Hokkaido. Figure V-28 shows tropical cyclone center positions when gale force ($\geq$34 kt) winds were first and last recorded at Mishima. It can be ascertained from this figure

that winds $\geq$34 kt generally do not begin until the storm is about 180 n mi away. Notice the preponderance of storms that generate gale force winds are south-southeast and northwest from Mishima and that those storm centers that track to the northwest of the area produce gale force winds of longer duration.

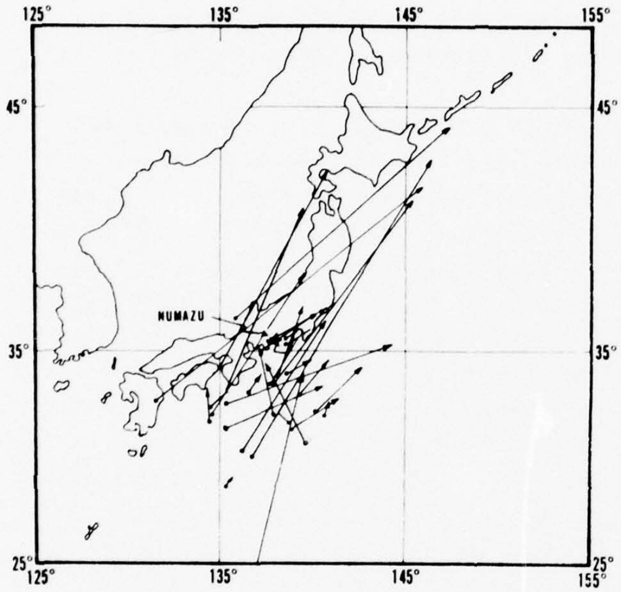

Figure V-27. Positions of 39 tropical cyclone centers when winds $\geq$22 kt first and last occurred at Mishima. (Based on hourly data for the months June-October during the years 1956-1974.)

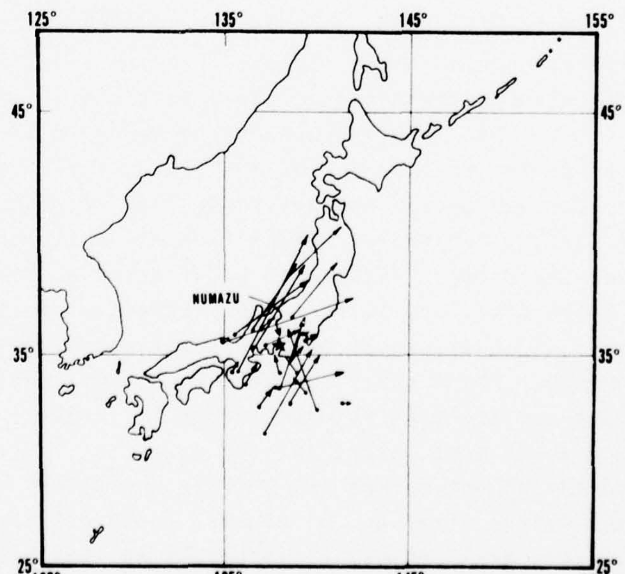

Figure V-28. Positions of 25 tropical cyclone centers when winds $\geq$34 kt first and last occurred at Mishima. (Based on hourly data for the months June-October during the years 1956-1974.)

3.2.3 Wind And Swell Wave Action

The combination of the extreme depth and geographical orientation of Suruga Bay makes the area susceptable to extreme wave action -- often on short notice. Because of the depth of the bay, wave activity in the open areas of the bay is to be considered similar to that of the open ocean (under certain circumstances). Incoming wind and swell wave energy does not begin to come under the shoaling effect until it reaches the extreme northern reaches of the bay.

The northeast-southwest geographical orientation of Suruga Bay makes it extremely vulnerable to the wind and wave condition of the ocean and provides an unimpeded region for winds from the southwest quadrant to flow. The Numazu Operating Area is located in the northern reaches of the bay in extremely deep water and fully exposed to the aforementioned southwesterly flow of wind. The result is that the operating area is placed at the focal point of a considerable amount of incoming wave energy -- produced both locally and at great distances.

The beach along the northern side of the bay can be considered steep and is composed of pea gravel. From Figure V-19 it can be seen that the bottom profile drops off rapidly to over 200 m in less than 1 n mi. The Japanese government has built a massive sea wall (approximately 50 ft high) that stretches along the entire northern coast of Suruga Bay and on the southwestern flank of the Numazu Harbor.

Maximum wave action generated by winds will occur when tropical cyclones pass to the west of the Numazu Operating Area. The resultant winds from the southwestern quadrant will flow unimpeded the entire length of the Suruga Bay, and depending on the size of the storm and the area over which the generating wind blows (fetch), produce wave heights typically associated with such winds encountered in the open ocean.

For tropical cyclones passing to the east, as approximately 46% have done in the 28-year period 1947-1974, the effects of wind produced waves will be lessened by the northeasterly flow of winds interacting with the mountains of the Izu Peninsula. Under such circumstances however, wind waves generated over the shorter fetch will be of the high frequency type -- usually steep with a short time interval between successive crests.

Swell waves are characterized by long, smooth undulations of the sea surface. These waves result from storms located at great distances from the coast and the time between successive crests may be quite large. Such waves seldom, if ever, break in deep water as in Suruga Bay and unless very high usually do not affect small craft operations while they are operating in the deep water. They do, of course, cause rolling and pitching of large vessels. However, swell waves are important in that upon reaching shallow water the wave height increases markedly, perhaps by a factor of two or more. Thus when they

reach a depth shallow enough to break, they can give rise to immense surf which may cause damage or destruction to small craft or harbor installations.

Since Suruga Bay opens to the southwest, it is exposed to swells arising from the tropical cyclone generating area in the lower latitudes. These swells with their incumbent high energy approach the coast at high speeds and in the case of a large offshore disturbance such as a typhoon, the swell will ordinarily arrive before the disturbance. This situation could hamper a ship's efforts in attempting to reach a typhoon haven ahead of the storm.

The two types of waves, wind and swell waves, usually exist simultaneously at any time in the open waters of Suruga Bay. Often times the swell are completely obscured by the wind waves generated by local wind conditions. It is only near the shoreline in the Numazu Operating Area, where the swell begins to peak to greater heights, is the observer made aware of their presence. In this area, where critical wave conditions result from swell generated by storms occurring at considerable distances, local wind conditions may be of little value in determining significant wave and surf characteristics. A consideration of the orientation of isobars on a weather map will reflect large scale wind patterns and permit an estimate of the extent of the generation area and, consequently, the length of the fetch and the direction of wave propagation.

Table V-7 is an example of Fleet Numerical Weather Central's Wave Refraction/Surf Prediction based on the bottom topography of the Numazu Operating Area, direction of the incoming wave energy, and the period of the wave. The result is a "surf coefficient" that is dependent on the angle of incidence of the wave energy ray with respect to the beach. This surf coefficient is the equivalent to the ratio of the shallow water wave height and the deep water wave height. With this coefficient, an observer located in the deeper water of the operating area can estimate the height of waves passing his location and apply the surf coefficient to determine the height of the surf at the beach. For example, if a wave from the southwest with a height estimated to be 5 ft high in the deeper water and a period (measured crest to crest) of 10 sec, the surf height would range from 5 ft to 10 ft with an average of 7 ft. It should be noted that independent studies have found that the average period of typhoon generated waves is approximately 8-12 sec.

Table V-7. "Surf coefficients" determined by wave period and direction of wave energy. Resultant coefficients reflect the range of the coefficients with the average in parenthesis.

Direction of Wave Energy	Wave Period (crest to crest) Sec.									
	6	8	10	12	14	16	18	20	22	24
SOUTH	1.1-2.5 (1.3)	1.1-2.7 (1.5)	1.1-2.0 (1.5)	1.0-2.1 (1.5)	1.2-2.5 (1.6)	1.3-2.4 (1.8)	1.4-3.3 (2.1)	1.5-3.1 (2.1)	1.0-4.1 (2.2)	1.0-5.1 (2.4)
SOUTHWEST	0.9-1.7 (1.3)	1.0-2.0 (1.3)	1.0-2.0 (1.4)	1.2-2.2 (1.6)	1.1-2.5 (1.7)	1.3-2.6 (1.9)	1.4-2.5 (1.9)	1.5-2.9 (2.1)	1.4-3.0 (2.1)	1.5-3.0 (2.1)

Because of its geographical configuration, the above indicates that surf conditions near Numazu may be affected by distant storms that pass to the south or southwest, even though they may pose no threat to the Numazu Operating Area or show tendency of recurving. The swell generated by these and other storms travel at speeds (kt) of three times their crest-to-crest period. (That is, a swell with a period of 12 sec will progress outward from the generating area at 36 kt.) Eventually the "family" of swell separates with the longer period swell outdistancing the shorter periods. Decay rates of swell energy varies according to the size of the generating area and strength of the wind over the fetch. Typical tropical cyclones of typhoon intensity can generate sufficient energy such that swell from these storms can be felt at distances of 800-1000 n mi from the center of the generating area. Thus, a typhoon hitting Taiwan can result in high surf at Numazu.

3.2.4 Storm Surge and Tides

Storm surges result when a tropical cyclone crosses a coastline. They are caused by an interaction between wind stress on the water, the sharp drop in atmospheric pressure, and the shallowness of the harbor or bay.

Ships operating in Suruga Bay should not normally notice such a surge due to the extreme depths of the bay. More evident would be the wind generated waves and swells originating from the tropical cyclone system itself.

Tidal ranges near the Numazu Harbor area are quite small -- less than 2 ft for maximum ranges. Therefore, any surge associated with a tropical cyclone would tend to have a significant effect close to the harbor entrance where the water depth becomes shallower (approximately 45 fathoms).

For a more detailed discussion on the effects of tropical cyclones on Numazu, see Wixom, 1975.

3.3 THE DECISION TO EVADE OR REMAIN AT NUMAZU

3.3.1 Evasion Rationale

The responsibility for overall coordination of action to be taken by naval activities in the Numazu Operating Area has been assigned to Commander, Fleet Activities, Yokosuka.[11] The Naval Weather Service Facility, Yokosuka issues the local area forecasts for Numazu upon request.

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[11] Storm/typhoon doctrine and coordination procedures for naval forces operating in the COMNAVFORJAPAN area of responsibility has been established by COMNAVFORJAPAN INST 3140.1 series. For general information on tropical cyclone warnings the reader is referred to paragraphs 6 and 7 of Chapter I.

The commander must recognize the inherent dangers that exist when exposed to the possibility of hazardous weather while operating in the Numazu Operating Area. By proper utilization of meteorological products, especially the FWC/JTWC Tropical Cyclone Warnings, and a basic understanding of weather, the commander will be able to act in the best interest of his unit and to complete his mission when the unfavorable weather subsides. The following time table (in conjunction with Figures V-29 to V-33) has been set up to aid in these actions. The orientation of the threat axis in these Figures was derived by considering the general direction from which the tropical cyclones approached to within 180 n mi of the Numazu Operating Area. The time in days to reach the Numazu Operating Area was based on average speeds of movement of tropical cyclones affecting Numazu.

1. An existing tropical cyclone moves into or development takes place in Area A with long range forecast movement toward the Numazu Operating Area (recall that about 40% of all tropical storms and typhoons recurve):

   a. Review material condition of ship.

   b. Plot FWC/JTWC warnings and construct the danger area (see paragraphs 6 and 7 of Chapter I). Reconstruct the danger area for each new warning.

2. Tropical cyclone enters Area B with forecast movement toward the Numazu Operating Area (recall that prior to recurvature, tropical cyclones tend to slow in their forward motion and after recurvature, accelerate rapidly):

   a. Consideration should be given to ceasing operations and departing Suruga Bay. Sea state rather than wind conditions may be the governing factor at this stage.

   b. Continue plot of FWC/JTWC warnings.

   c. Prepare the ship for heavy weather. Ship should be alert for large long period swell and heavy surf.

3. Tropical cyclone enters Area C and is moving toward the Numazu Operating Area:

   a. The decision to evade the typhoon by departing the area for Yokosuka or other known typhoon havens in the Tokyo Bay area or evasion at sea must be made.

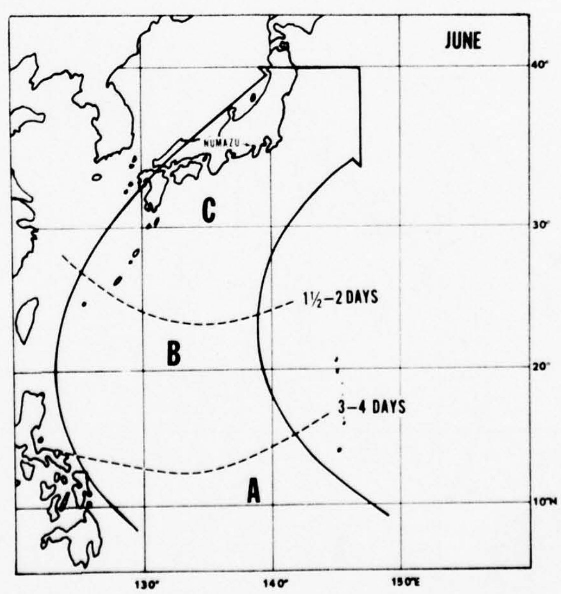

Figure V-29. Tropical cyclone threat axis for the Numazu Operating Area for the month of June.

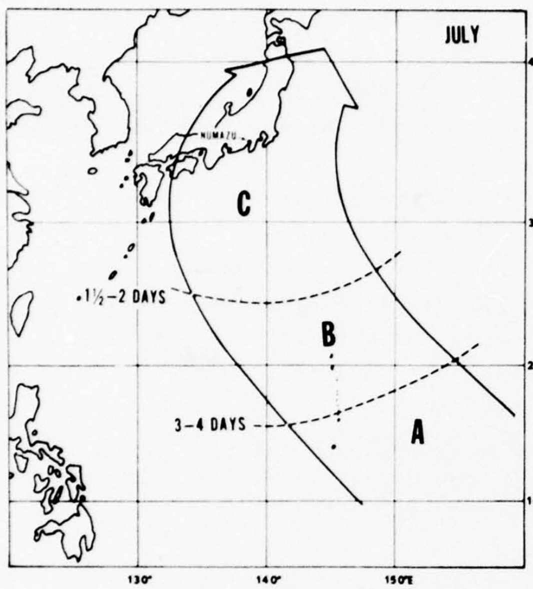

Figure V-30. Tropical cyclone threat axis for the Numazu Operating Area for the month of July.

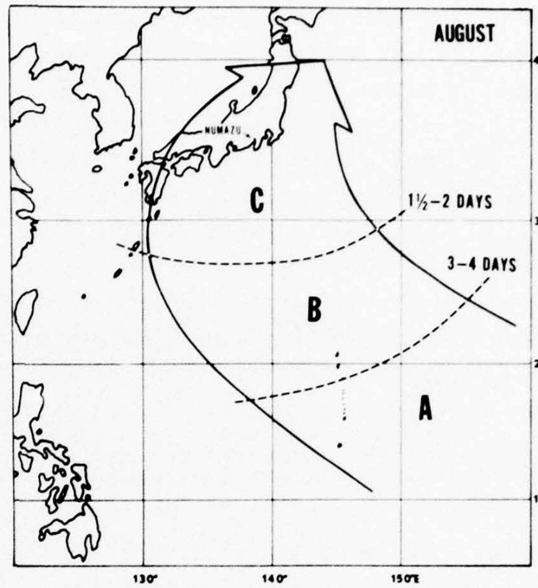

Figure V-31. Tropical cyclone threat axis for the Numazu Operating Area for the month of August.

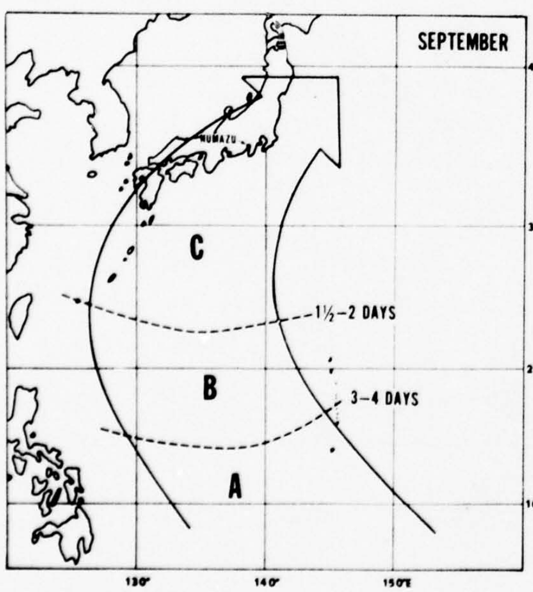

Figure V-32. Tropical cyclone threat axis for the Numazu Operating Area for the month of September.

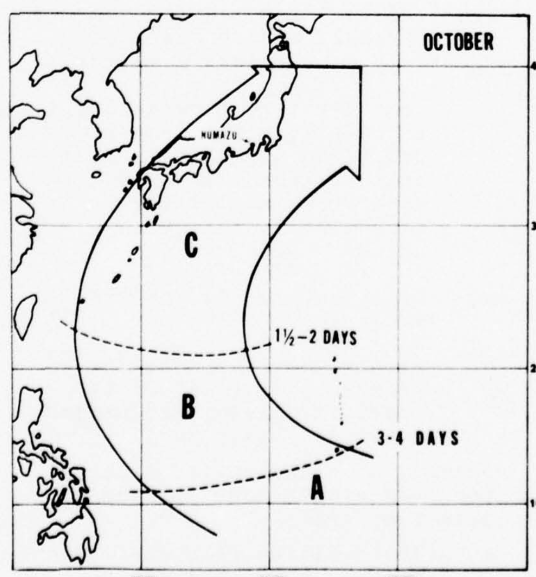

Figure V-33. Tropical cyclone threat axis for the Numazu Operating Area for the month of October.

3.3.2 Evasion To Yokosuka

The port of Yokosuka has been evaluated as an excellent typhoon haven for all sizes and types of vessels. In general, due to the geographical location, surrouding topographical features and harbor construction, the hazardous effects of wind and sea from a typhoon are greatly reduced. However, if crowded conditions exist within the port, which would reduce availability of pierside facilities, a Commanding Officer may elect to evade the typhoon at sea or anchor in Tokyo Bay.

3.3.3 Evasion In Tokyo Bay

Japanese Maritime Self Defense Force ships in the past have anchored in Tateyama Bay for typhoon passage to the east of Tokyo Bay. They also make use of Kisarazu Harbor (see Figure V-1).

Merchant vessels have, at times, depending on the direction of the tropical storm or typhoon CPA, anchored in the following areas:[12]

(1) Tropical cyclone passage to the east or south of Tokyo Bay: anchor in Chiba Harbor or Kisarazu Harbor.

(2) Tropical cyclone passage to the west or north of Tokyo Bay: anchor in Kaneda Bay.

Vessels carrying a dangerous cargo must anchor as directed by the Japanese Maritime Safety Office.

Ships requiring a pilot to transit the Uraga Suido Traffic Route may be unable to secure pilot services if winds are greater than about 35 kt because pilots embark and debark from small motor launches.

3.3.4 Evasion At Sea

The widely held doctrine of evasion at sea rather than remaining in port for the single purpose of minimizing typhoon related damage is not generally recommended if the ship can reach Yokosuka. However, if putting to sea is desirous, each tropical storm or typhoon must be considered as differing from those preceding it. The accompanying weather situation must be fully understood. To establish one technique or rule to avoid the danger area is not practical.

In general, the effects of sea/swell generated by a tropical cyclone may reduce the speed of advance (SOA), thereby increasing the time required to reach the open sea (see Paragraph 5, Chapter I). If a ship is caught in the sea/swell pattern ahead of a tropical cyclone, in particular an intense tropical storm or typhoon, the SOA may be reduced to the point that the ship will be unable to maneuver to clear the danger area.

[12] See Defense Mapping Agency Hydrographic Center charts H.O. 97151 and H.O. 97143.

NUMAZU

If the typhoon is forecast to follow a recurving track, with a CPA to the east of Numazu, then a course downsea/downwind, in the left or navigable semicircle may be advisable.

Any course to the north along the east coast of Honshu (north of Tokyo Bay) is considered unwise. The possibility of being overrun exists if the storm accelerates and/or turns suddenly to the north. The average speed of advance in the higher latitudes (30°-40°N) of tropical cyclones is about 25 kt; however, they have been tracked as fast as 50 kt. Typhoon wind intensities tend to decrease as the system moves into the northern latitudes but, nevertheless, can be quite destructive.

Remaining in the northern regions of Suruga Bay and riding out the storm should only be considered if the certainty of the typhoon's passage well to the east of the area can be ascertained. Some degree of protection may be offered by the mountains along the eastern side of the bay protecting the area from the northeasterly flow around the cyclone's center. Additionally, the sea state will not be as destructive because the fetch will not be as great for the northeasterly wind as it would be for a southwesterly wind.

4. IWAKUNI AND KURE

SUMMARY

The conclusions reached by this study are first that Kure Harbor is a favorable typhoon "haven" for all ships; and second, Iwakuni Harbor, although not recommended as a "haven," has easily accessible anchorages close by which are considered safe during typhoon passage. These conclusions are based on the following:

1. The location and topography of the entire Iwakuni/Kure area significantly reduces the effects of winds attending tropical cyclones.

2. Anchor holding in the designated anchorage areas is rated as excellent.

3. Surge effect is almost negligible and wave heights are not severe in the designated anchorage areas.

4. Port services and repair facilities at Kure (also available to ships at Iwakuni) are among the best in all of Japan.

5. Conversations with local harbor and meteorology officials.

4.1 LOCATION AND TOPOGRAPHY OF IWAKUNI AND KURE AND THEIR EFFECTS ON TROPICAL CYCLONES

4.1.1 General

The mountainous terrain of the islands of Honshu, Kyushu and Shikoku, with elevations exceeding 3000 ft, would lead one to expect that the winds of a tropical cyclone would be greatly reduced before reaching the Hiroshima Bay region. This is, in fact, the case when storms pass either to the west or the east of the bay region.

When storms pass to the west, the wind will normally be reduced 35-50% while storms passing to the east will usually have their winds reduced approximately 60%. Also it appears that southerly winds coming through the Bongo Straits and Inland Sea have the path of least resistance into the Hiroshima Bay area. Generally this would be the case when a storm passes to the west. Further, a very strong storm passing directly through the Bongo Straits would probably give the worst conditions in the Hiroshima Bay region.

4.1.2 Hiroshima Bay Region

Hiroshima Bay is that portion of the Inland Sea of Japan associated with the city of Hiroshima. The area of Hiroshima Bay was covered by air mining during World War II. Channels have been swept by both U.S. and Japanese mine sweepers. Ships negotiating Hiroshima Bay should remain in the swept areas listed in the HYDROPACS and DAPAC (see H.O. 110, Sec. (6-52)-(6-61), and H.O. Chart 97267).

As seen in Figures V-34 and V-35, Iwakuni is located on the western side of the bay in a relatively flat, open area while Kure is embedded in a region of mountains and mountainous islands with almost complete protection from all directions.

Oshima Island, located in south Hiroshima Bay, and the numerous smaller islands offer effective barriers to winds and seas from the south. They also are responsible for the almost negligible surge and relatively moderate seas in the bay with southerly winds. The lee side of any of the larger islands in the bay area provide substantial protection from both wind

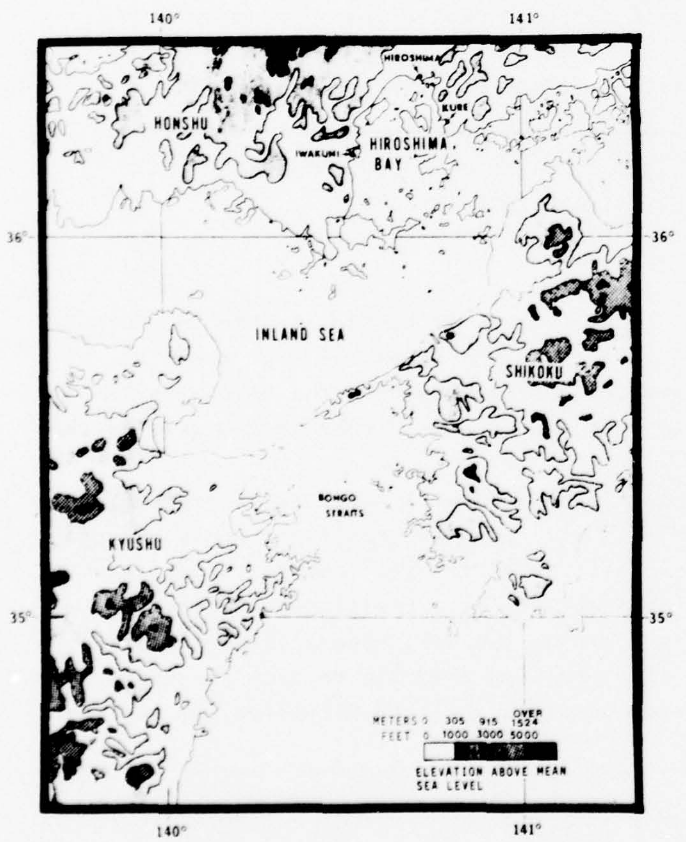

Figure V-34. Hiroshima Bay relative to the main Japanese islands of Honshu, Kyushu and Shikoku.

and sea. However, draft and the allowable radius of swing must be considered when choosing a refuge. Additionally, many of the islands, both large and small, have commercial oyster beds on their northern sides. Destruction of these beds by foreign flag vessels while seeking refuge should be a major consideration of ship captains so as to eliminate, to the greatest degree possible, the straining of relations with local fishermen and authorities.

Area A depicted in Figure V-35 is free from all the complications listed above and gives excellent protection from the wind and sea, particularly from the south and the west (storm passage to the west). The depth is about 60 ft with a mud bottom characterized by good holding. There should be no problem of crowding by other ships or traffic. Area A would also give, for larger vessels, good protection from the wind and sea when the winds are from the east and northeast (storm passage to the east). It might be prudent for small boats to journey to Area D when winds north or east are expected. Area C of Figure V-35 has all the good qualities of Area A and would provide excellent protection when the winds are from the north and east (storm passage to the east). The one drawback to Area C is a relatively shallow depth of approximately 25 ft at its center. Area B in Figure V-35 is a region of strong winds and strong currents and thus should be avoided.

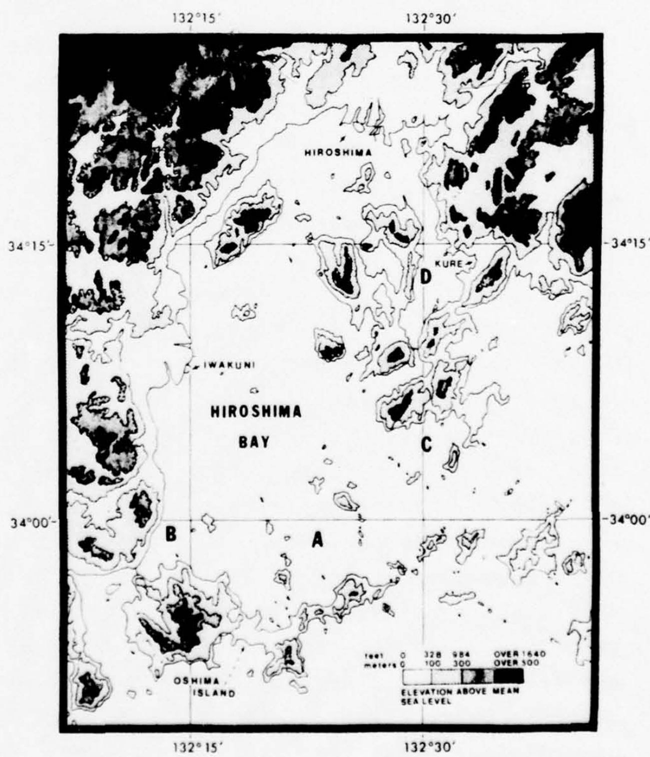

Figure V-35. Hiroshima Bay region.

4.1.3 Iwakuni

The port of Iwakuni (commercial) and the military harbor are sometimes mistakenly considered one and the same. The latter, operated by the United States Marine Corps Air Station, is located about three miles south of the commercial port (see Figure V-36).

The military port is small in size, has limited facilities, and a minimum depth of 18 feet at its single pier. The harbor is enclosed by a rocky breakwater which is partially covered at high water. The entrance to the harbor is safe for deep draft vessels for a period of only two hours before and after high tides (LST's have clearance at all times). Harbor entrance depth is reduced to two fathoms during low tide.

Four anchorages are available in the outer harbor area with 13 fathoms at low water.

Due to the relative openness of Iwakuni, neither the harbor nor the anchorages are recommended as preferred locations during tropical cyclone passage. Areas A, C, and D (in Kure Harbor), shown in Figure V-35, are the locations recommended.

4.1.4 Kure

Kure Harbor (see Figures V-35 and V-37), is located in the eastern sector of Hiroshima Bay and is literally landlocked by mountainous terrain, some of which exceed 360 meters (1181 feet) in height. To the north and east the mountains are highest, while to the west the maximum height of the islands ranges from 120 to 240 meters (394-787 feet). Islands to the south and southwest reach heights greater than 360 meters (1181 feet). These mountains are a formidable barrier to strong winds and accompanying seas. However, as can be seen from Figure V-35, the ridge lines north of Kure are aligned along a northeast-southwest axis so that one could expect the harbor to experience its strongest winds from the northeast (tropical cyclone passage to the east). Area D in the outer harbor (Figures V-35 and V-37), is the "typhoon anchorage" suggested for large vessels by Kure Harbor authorities. Area D is extremely well protected from westerly winds and would appear to be most open to northerly winds. The mud bottom, ranging from 18-22 meters (60-72 feet) in depth, is characterized by good holding. Smaller vessels usually utilize the shelter of the various coves found around the periphery of the harbor area or remain at pierside.

The weather office is located in the inner harbor as shown in Figure V-37. The winds recorded should be representative of those in the inner harbor but most probably are not representative of the winds in Area D. When the winds are from the north or south, Area D would probably experience higher winds than the inner harbor. When the winds are from the west Area D should experience lighter winds than the inner harbor. However, regardless of wind direction or speed, Area D has been utilized and praised for its security and proclaimed as the best location for large vessels at Kure.

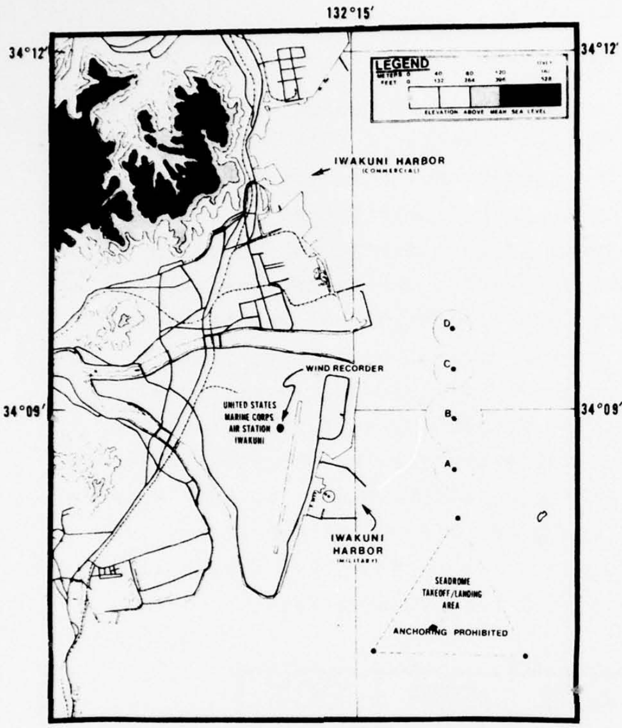

Figure V-36. Iwakuni Harbor

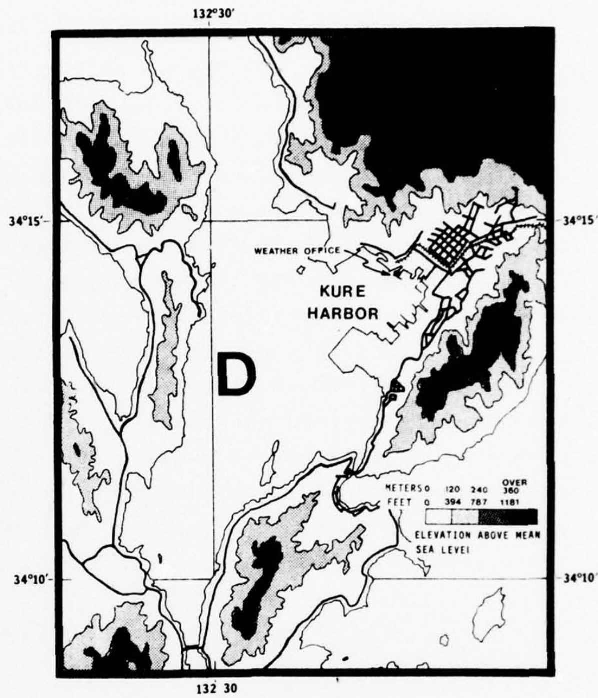

Figure V-37. Kure Harbor

There are six mooring buoys available within the inner harbor as listed in the navigation publications. The Japanese Maritime Self Defense Force (JMSDF) maintains control over a number of other buoys in the inner harbor. Their use must be coordinated through the JMSDF.

Excellent dry docks and repair facilities are available at Kure with a large part of the waterfront area being occupied by the docks and buildings of Ishikawajima-Harima Heavy Industries, LTD (IHI). IHI has the capacity to handle and repair ships over 100,000 tons.

The excellent anchorages, docks and repair facilities coupled with the exceptional protection from winds and seas accompanying tropical cyclones has given Kure the reputation of being one of the best, if not the best, typhoon havens in all of Japan. This reputation and abundance of facilities has in the past lured many ships both large and small to seek refuge in Kure, thus presenting the harbor with its only notable problem -- that of crowding. It should be noted that there have been no incidents related to crowding at Kure since records have been kept; however, the potential is there when a large number of vessels is present.

4.2 TROPICAL CYCLONES AFFECTING IWAKUNI AND KURE

4.2.1 Tropical Cyclone Climatology For Iwakuni And Kure

Tropical cyclones which affect Iwakuni and Kure generally form in an area bounded by the latitudes 5N and 30N between longitudes 120E and 165E. The latitudinal boundaries shift poleward in the summer months and equatorward in winter in response to seasonal changes of the synoptic environment.

It is possible for tropical cyclones to form during any month or season; however, those affecting the Japanese Islands, and hence, Iwakuni and Kure, are confined for the most part to the spring through fall months, with late summer and early fall being the most likely period for an occurrence.

For this study the period June-October 1947-1972 was investigated.[13] During this period 74 tropical cyclones passed within 180 n mi of Iwakuni and Kure and are defined as "threats." Figure V-38 gives the frequency distribution of threat occurrences by 5-day groupings through the five month period. Note in Figure V-38 that August and September are the preferred months for storms affecting the Iwakuni/Kure area. Notice also in Figure V-38 that a majority of the storms affecting Iwakuni and Kure are of the recurving variety.

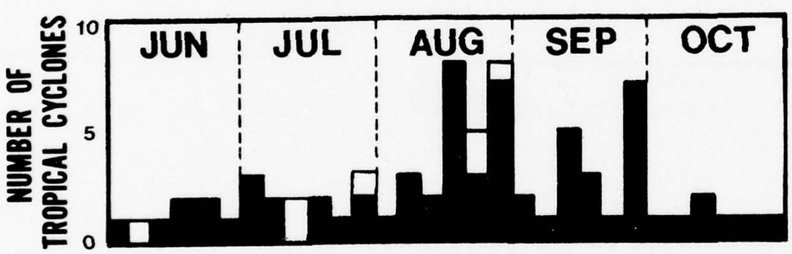

Figure V-38. Frequency distribution of the number of tropical cyclones that passed within 180 n mi of Iwakuni and Kure. Subtotals are based on 5-day periods for tropical cyclones that occurred during 1947-1972. Out of a total of 74 storms, 67 (91%) were recurvers (had a northeasterly direction of motion at the closest point of approach) and are indicated by the shading.

Figure V-41 illustrates the "threat" tropical cyclones according to the compass octant from which they entered the 180 n mi radius threat area. The circled numbers indicate the total that entered from an individual octant. The adjacent numbers express this as a percentage. It is evident that the majority of tropical cyclones (56%) entered the threat area from a sector extending from the south-southwest.

[13]From Chin (1972) for years 1947-1970, and from Annual Typhoon Reports for the years 1971-1972 (FWC/JTWC, 1971 and 1972).

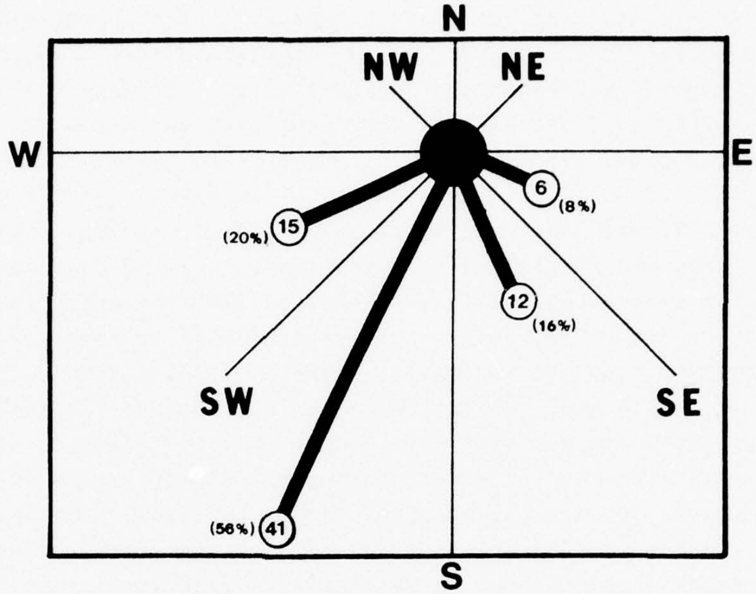

Figure V-39. Direction of approach to Iwakuni and Kure of the tropical cyclones (1947-1972) that passed within 180 n mi of Iwakuni and Kure. Circled numbers indicate the number that approached from each octant. The number in parenthesis is the percentage of total sample (74) that approached from that octant.

Table V-8 lists the average speeds of movement for tropical cyclones which affected Iwakuni/Kure for the months of June through October. The information presented in Table V-8 was used in the preparation of Figures V-40 through V-44.

Table V-8. Average climatological speeds of movement of tropical cyclones (kt) by 5-degree latitude bands for the months of June-October for the tropical cyclones affecting Iwakuni and Kure.

LATITUDE BAND (N)	AVERAGE FORWARD SPEED OF MOVEMENT (KT)					AVERAGE OF THE 5-MONTHS (KT)
	JUN	JUL	AUG	SEP	OCT	
30-35 N	25	13	12	20	17	17.4
25-30	17	11	9	15	14	13.2
20-25	12	11	10	11	12	11.0
15-20	10	10	10	11	11	10.4

IWAKUNI/KURE

Figures V-40 to V-44 represent an analysis of the probability of a tropical cyclone passing within 180 n mi of Iwakuni and Kure. The solid lines of Figures V-40 to V-44 represent the "percent threat" for any storm location. The dashed lines represent approximate approach times to Iwakuni/Kure computed from the average tropical cyclone speed of movement for June-October for tropical cyclones affecting Iwakuni/Kure (Table V-8). As an example, in Figure V-40 a storm located at 128E and 23N has a 40% probability of passing within 180 n mi of Iwakuni and Kure, and it could hit Iwakuni/Kure in 1-1/2 to 2 days.

Note the significant shift in the direction from which the "threat" tropical cyclones approach Iwakuni/Kure in Figures V-40 to V-44. In June the "threat" is generally from the southwest; whereas, in July and August, it is from the south and southeast. During September and October the threat is generally out of the south and southwest. Note that the majority of the storms make their approach from the south and southwest indicating that they have undergone recurvature and are therefore beginning to weaken even before reaching Japan. This weakening coupled with the mountainous topography surrounding the Hiroshima Bay region accounts for substantially reduced winds associated with tropical cyclones. It must be kept in mind that although the effects of storms are reduced quite effectively, destructive winds can and may occur in the Bay Region with any tropical cyclone.

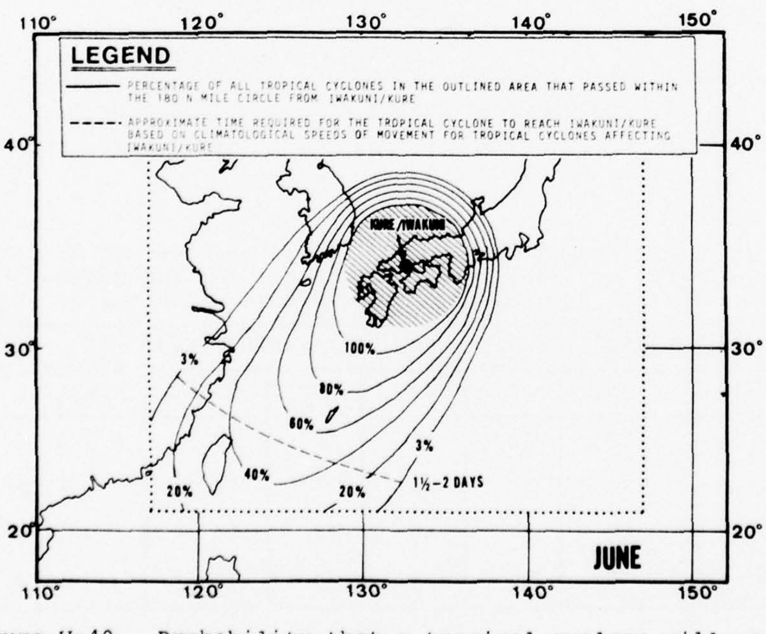

Figure V-40. Probability that a tropical cyclone will pass within 180 n mi of Iwakuni/Kure for the month of June. (Based on data from 1947-1972.)

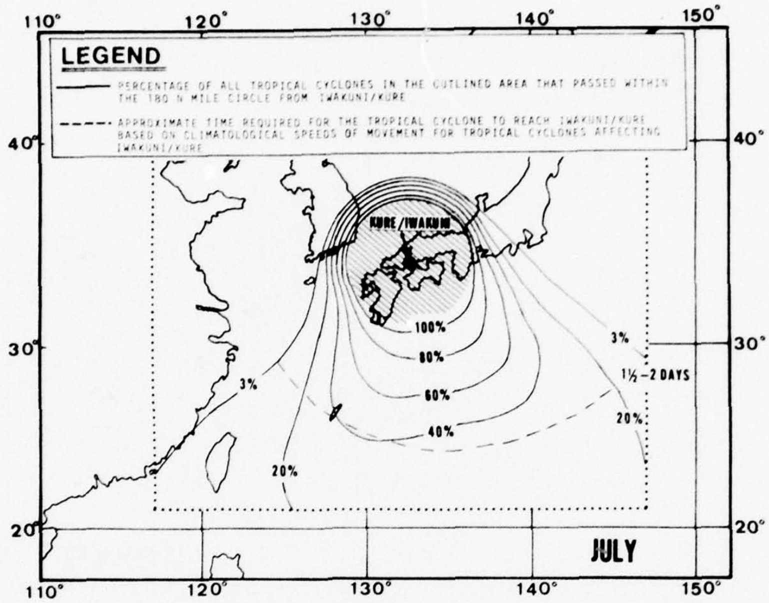

Figure V-41. Probability that a tropical cyclone will pass within 180 n mi of Iwakuni/Kure for the month of July. (Based on data from 1947-1972.)

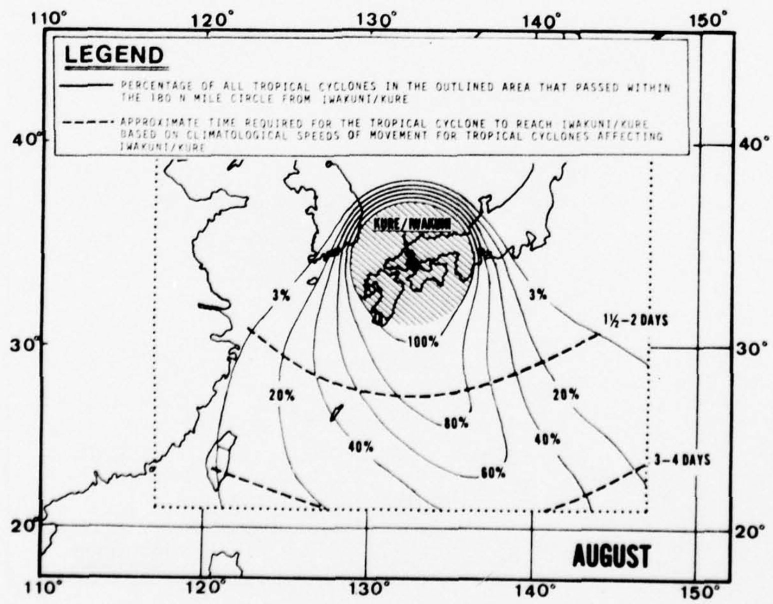

Figure V-42. Probability that a tropical cyclone will pass within 180 n mi of Iwakuni/Kure for the month of August. (Based on data from 1947-1972.)

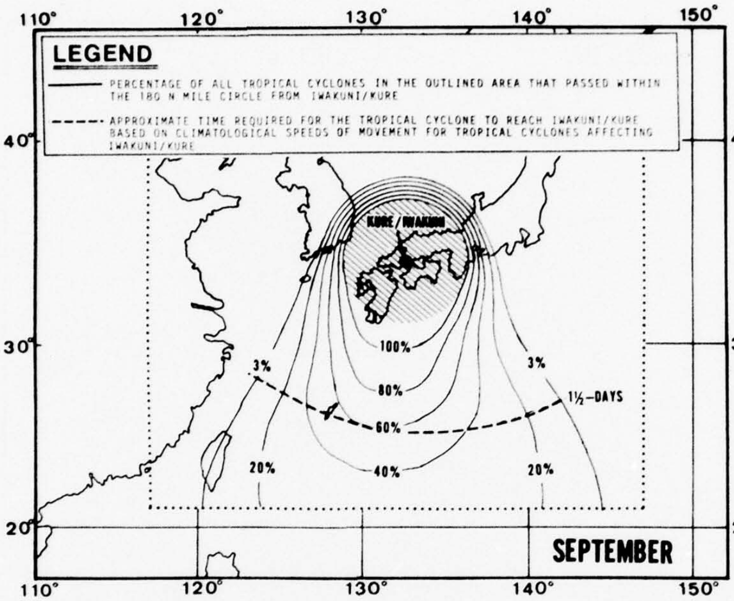

Figure V-43. Probability that a tropical cyclone will pass within 180 n mi of Iwakuni/Kure for the month of September. (Based on data from 1947-1972.)

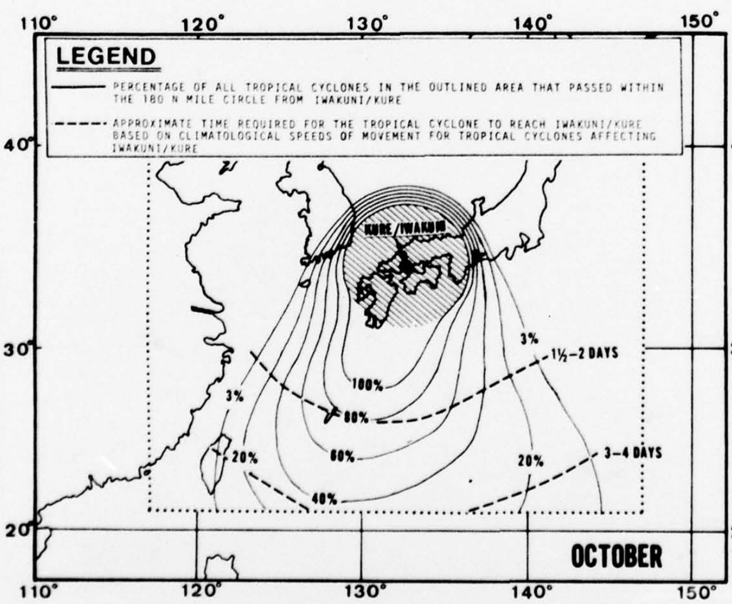

Figure V-44. Probability that a tropical cyclone will pass within 180 n mi of Iwakuni/Kure for the month of October. (Based on data from 1947-1972.)

4.2.2 Tropical Cyclones Affecting Iwakuni

During the June-October period in the 18 years 1955-1973 (excluding 1958), a total of 53 tropical cyclones or an average of 3 tropical cyclones per year have passed within 180 n mi of Iwakuni (and Kure). The largest number that occurred in any single year was 4 (1955, '59, '62, '68, and '71). Table V-9 groups the 53 storms according to their effects at Iwakuni. It can be seen in Table V-9 that of the total of 53 storms, 14 (26%) resulted in winds of 22 kt or greater and only 6 (11%) gave gale force winds.

Table V-9. Extent to which tropical cyclones affected Iwakuni, June through October, 1955-1973 (excluding 1958) (based on hourly wind observations).

Number of tropical cyclones that passed within 180 n mi of Iwakuni	53
Number of tropical cyclones that resulted in winds greater than or equal to 22 kt	14 (26%)
Number of tropical cyclones that resulted in winds greater than or equal to 34 kt	6 (11%)

The strongest sustained winds observed at Iwakuni associated with tropical cyclones were two 45-kt occurrences in 1955. It should be noted that stronger winds have been attributed to extratropical systems in the winter months.

Figure V-45 illustrates the positions of the 14 tropical cyclone centers previously mentioned when 22-kt winds first and last occurred at Iwakuni.

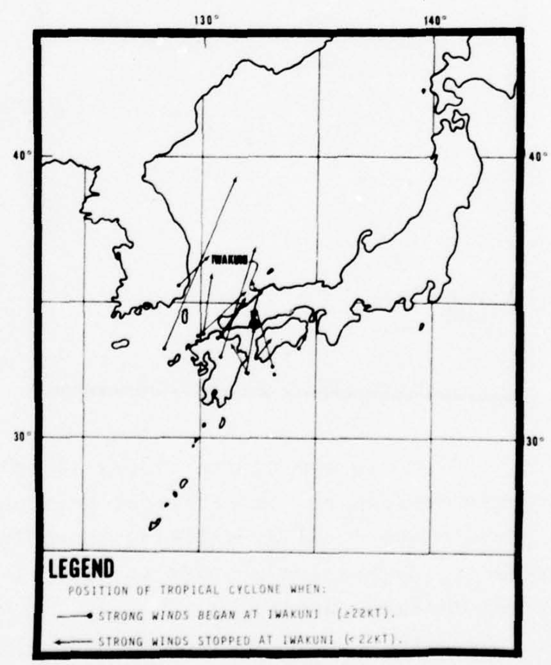

Figure V-45. Position of tropical cyclone centers when winds ≥22 kt first and last occured at Iwakuni. (Based on data from 1955-1973, excluding 1958.)

IWAKUNI/KURE

Figure V-46 illustrates the storm locations when winds first and last exceeded 33 kt. Of the 53 tropical cyclones which approached within 180 n mi of Iwakuni (and Kure), 33 (63%) were observed to pass to the east, 19 (36%) to the west, and one directly over the harbor area (1970). These observations, coupled with Figure V-45 and V-46, indicate a bias for storms passing west of and within 120 n mi of Iwakuni to be those most likely to give strong winds up to and exceeding gale force. The length of the line segments in Figures V-45 and V-46 also present a rough estimate of wind duration of Iwakuni. For the most part the line segments of Figure V-46 represent less than 100 n mi which suggests that a tropical cyclone moving with a speed of 25 kt would give gale force winds at Iwakuni for less than 4 hours.

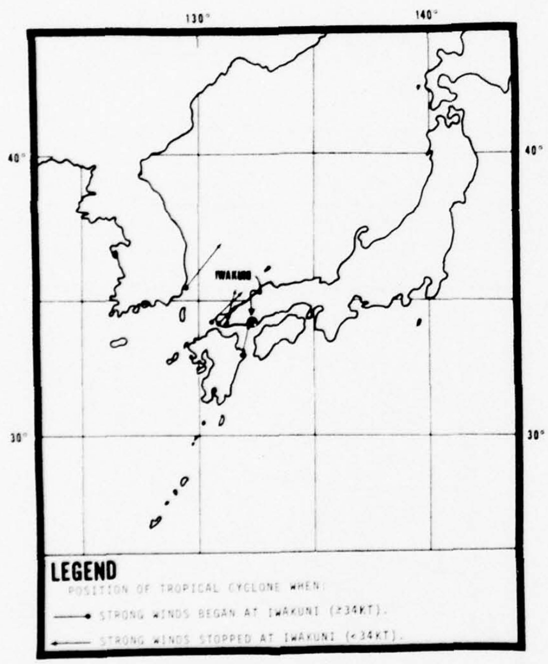

Figure V-46. Position of tropical cyclone centers when winds greater than or equal to 34 kt first and last occurred at Iwakuni. (Based on data from 1955-1973, excluding 1958.)

Due to the counterclockwise rotation of tropical cyclones in the Northern Hemisphere, those storms passing to the west of Iwakuni can be expected to give southerly winds shifting to westerly. If the storm passes to the south and east, southeasterly winds would first be experienced, followed by easterly and/or northerly winds.

4.2.3 Wave Action In Hiroshima Bay (Iwakuni)

Table V-10 lists the significant wave heights which could be observed at the Iwakuni Harbor anchorages (Anchorage A-D of Figure V-36), and Areas A and C (Figure V-35) with various wind speeds and directions. Notice in Table V-10 that the maximum wave heights at the Iwakuni Harbor anchorages (A through D) will occur when the winds are from the south (storm passage to the west), while Areas A and C will have waves 7 ft or less. Also notice in Table V-10 that winds from the north give the highest waves in Area A and winds from the west give the highest waves in Area C.

Table V-10. Significant wave heights ($\bar{H}$ 1/3) in ft that could be expected at the Iwakuni anchorages (A-D of Figure V-36), and Areas A and C (Figure V-35) with various wind speeds and directions. X indicates negligible wave heights (less than 4 ft).

WIND (KT)	IWAKUNI ANCHORAGES				AREA A				AREA C			
	N	S	E	W	N	S	E	W	N	S	E	W
35 kt	4.0 ft	5.0	4.0	X	6.0	X	X	X	X	X	X	4.5
45	5.0	6.5	5.5	X	7.0	5.0	5.5	5.5	X	5.0	X	6.5
55	6.5	9.0	6.0	X	9.5	6.0	6.5	6.5	X	6.0	4	8.5
65	8.5	11.0	7.0	X	10.5	6.5	7.0	7.0	5	7.0	5	10.0

4.2.4 Storm Surge in Hiroshima Bay (Iwakuni)

Storm surge may be defined as an abnormal rise of the sea along a shore as the result of winds and pressure drop associated with a storm. These surges are most pronounced along the south coast of the Japanese island chain where the bays are open to the Pacific Ocean.

Due to its sheltered position within the Inland Sea, the numerous islands (notably Oshima Island to the south), and the fact that winds are significantly reduced before reaching the Hiroshima Bay area, storm surge is negligible. These points were emphasized quite strongly in conversations with local harbor and weather authorities. Records are not kept on storm surge in Hiroshima Bay and no significant damage or incident has been attributed to this phenomenon.

4.2.5 Tropical Cyclones Affecting Kure

During the June-October periods in the 18 years 1955-1972, a total of 53 tropical cyclones or an average of 3 tropical cyclones per year passed within 180 n mi of Kure. The largest number that occurred in any single year was 4 (1955, '59, '62, '68, and '71). Table V-11 groups the 53 storms according

to their effects on Kure. It can be seen in Table V-11 that of the total of 53 storms, 24 (45%) resulted in winds greater than or equal to 22 kt and only 6 (11%) gave winds greater than or equal to 34 kt.

Table V-11. Extent to which tropical cyclones affected Kure, June through October, 1955-1972.

Number of tropical storms that passed within 180 n mi of Kure	53
Number of tropical cyclones that resulted in winds greater than or equal to 22 kt	24 (45%)
Number of tropical cyclones that resulted in winds greater than or equal to 34 kt	6 (11%)

Figure V-47 shows the positions of the tropical cyclone centers when winds first and last exceeded 21 kt at Kure. Figure V-48 illustrates the storm centers when the winds first and last exceeded 33 kt. As noted earlier, out of the total of 53 tropical cyclones approaching within 180 n mi of Kure (and Iwakuni) during the period investigated, most passed to the east (approximately 63%) with one occurrence of a storm passing directly over the harbor area -- Typhoon Anita in 1970.

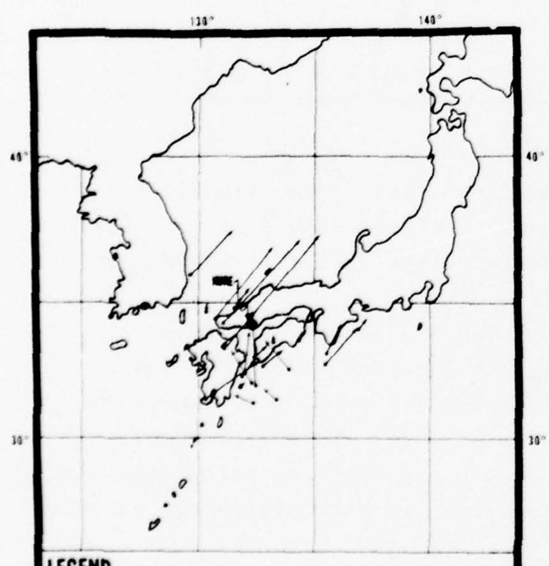

Figure V-47. Position of tropical cyclone centers when winds greater than or equal to 22 kt first and last occurred at Kure. (Based on data from 1955-1972.)

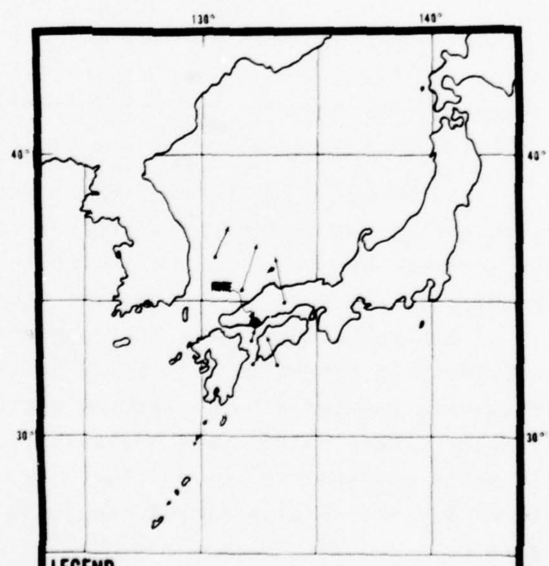

Figure V-48. Position of tropical cyclone centers when winds greater than or equal to 34 kt first and last occurred at Kure. (Based on data from 1955-1972.)

It can be seen in Figures V-47 and V-48 that the storm centers must be north of 31N before winds exceeding 22 kt and north of 32N before gale force winds are observed at Kure. Figure V-47 also suggests that storms passing to the west may have a longer duration of winds in the 22-33 kt range, than storms which pass to the east.

The strongest winds recorded at Kure that could be associated with a tropical cyclone in the period 1937-1972 were in 1970, when Typhoon Anita passed directly over the city. The maximum sustained winds recorded were 51 kt from the northeast. It should be noted that stronger winds have been attributed to extratropical systems in the winter months.

4.2.6 Wave Action In Kure Harbor

Table V-12 lists the significant wave heights which could be observed in Area D at Kure (see Figures V-35 and V-37) with winds of various speeds and directions. Observe in Table V-12 that the maximum significant wave heights will occur when winds are from the north. Wave action in the inner harbor should be less than that in Area D.

Table V-12. Significant wave heights ($\bar{H}$ 1/3 in ft) that could be expected in Area D of Kure Harbor area with wind speeds of 35, 45, 55, and 65 kt. X indicates negligible wave heights (less than 4 ft).

WIND SPEED (KT)	WIND DIRECTION			
	N	S	E	W
35	4.0 ft	X	X	X
45	5.5	X	X	X
55	6.5	4.0	4.5	X
65	7.5	5.0	5.0	X

4.2.7 Storm Surge In Kure Harbor

Storm surge is defined as an abnormal rise of the sea along a shore resulting from winds and the pressure drop associated with intense storms. Storm surge is adjudged to be negligible and hence should produce no significant damage.

For a more detailed discussion on the effects of tropical cyclones on Iwakuni and Kure, see Manning, 1975.

4.3 THE DECISION TO EVADE OR REMAIN AT PORT

4.3.1 General

There is no local heavy weather readiness procedure established for ships in port at Iwakuni and Kure. However, there are certain precautions suggested by Japanese Maritime Safety Agency officials. These suggestions plus additional conclusions for particular areas (Areas A, C, and D in Figures V-35 and V-37) form the basis for the following paragraphs.

For general information on tropical cyclone warnings, refer to paragraphs 6 and 7 of Chapter I.

4.3.2 Evasion Rationale

A most important aspect of any decision concerning heavy weather is an early appraisal of the threat posed by an individual tropical cyclone. The preparations must begin when enough time remains to allow flexibility in the evasion plan. To facilitate early action, the following time table has been devised in conjunction with Figures V-49 through V-53.

I. An existing tropical cyclone moves into, or development takes place in Area A of Figures V-49-V-53 with forecast movement toward Iwakuni/Kure.

a. Review material condition of ship. It may be necessary to move to recommended anchorages.

b. Reconsider any maintenance that would render the ship incapable of getting underway in 48 hr if need be, or riding out the storm at anchor.

c. Plot FWC/JTWC, Guam warnings if issued and construct the danger area. Reconstruct the danger area for each new warning.

II. Tropical cyclone enters Area B of Figures V-49 through V-53, with forecast movement toward Iwakuni/Kure.

a. Reconsider any maintenance that would render the ship incapable of getting underway or moving to a new anchorage prior to expected time of strong winds within the area.

b. All ships begin planning course of action to be taken if a shift in anchorage is anticipated.

III. Tropical cyclone enters Area C of Figures V-49 through V-53 with forecast movement toward Iwakuni/Kure.

a. Execute plans made in step II with the aid of information in the following paragraphs if the ship is in port at Iwakuni or Kure.

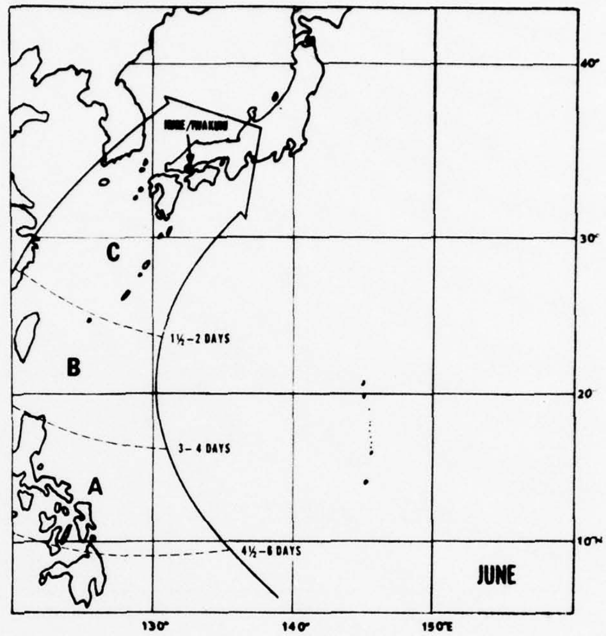

Figure V-49. Tropical cyclone threat axis for the month of June. The area within the arrow approximates a 30% or greater probability of a tropical cyclone coming within 180 n mi of Iwakuni/Kure. Approach times are based on typical speeds of movement for tropical cyclones affecting Iwakuni/Kure.

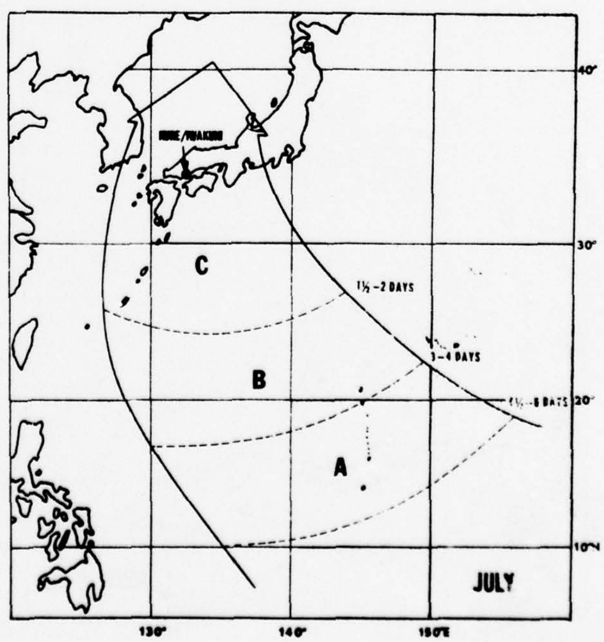

Figure V-50. Tropical cyclone threat axis for the month of July. The area within the arrow approximates a 30% or greater probability of a tropical cyclone coming within 180 n mi of Iwakuni/Kure. Approach times are based on typical speeds of movement for tropical cyclones affecting Iwakuni/Kure.

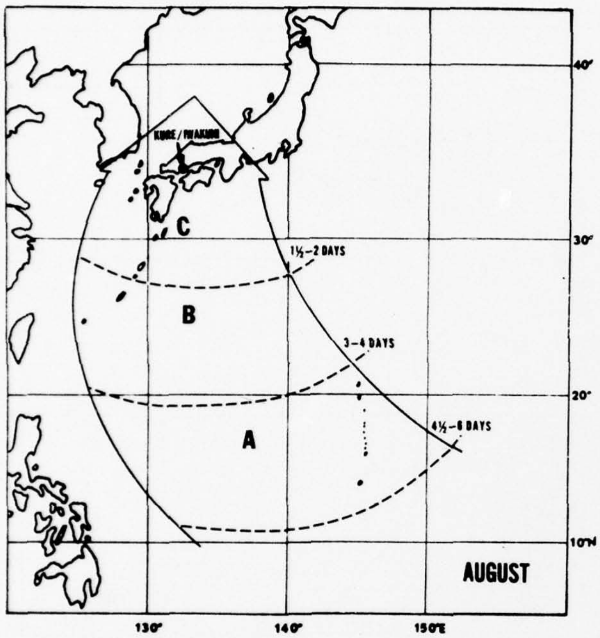

Figure V-51. Tropical cyclone threat axis for the month of August. The area within the arrow approximates a 30% or greater probability of a tropical cyclone coming within 180 n mi of Iwakuni/Kure. Approach times are based on typical speeds of movement for tropical cyclones affecting Iwakuni/Kure.

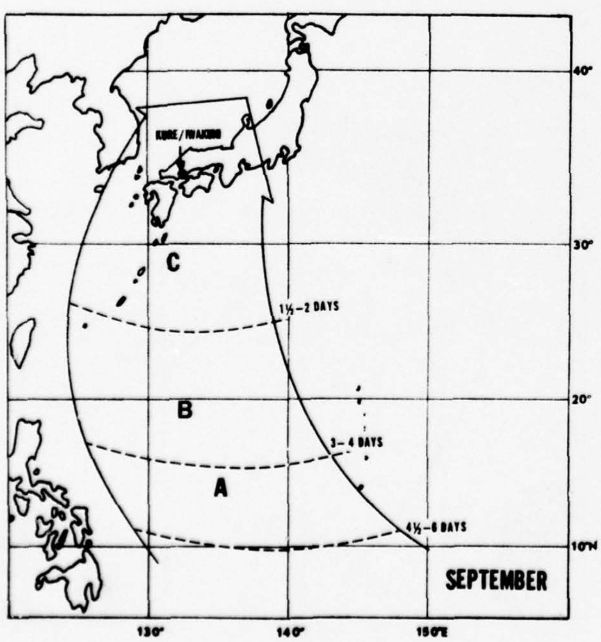

Figure V-52. Tropical cyclone threat axis for the month of September. The area within the arrow approximates a 30% or greater probability of a tropical cyclone coming within 180 n mi of Iwakuni/Kure. Approach times are based on typical speeds of movement for tropical cyclones affecting Iwakuni/Kure.

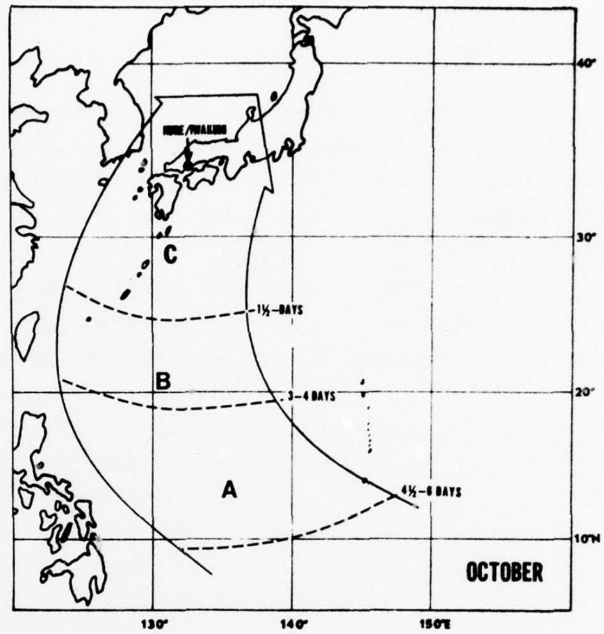

Figure V-53. Tropical cyclone threat axis for the month of October. The area within the arrow approximates a 30% or greater probability of a tropical cyclone coming within 180 n mi of Iwakuni/Kure. Approach times are based on typical speeds of movement for tropical cyclones affecting Iwakuni/Kure.

4.3.3 Remaining In Port At Iwakuni/Kure

Remaining in port at Iwakuni (considering Areas A and C of Figure V-35 as typhoon anchorages for Iwakuni) and Kure (considering Area D of Figures V-35 and V-37) is the recommended course of action for all ships. As stated previously, Kure is considered to be one of the best, if not the best, typhoon haven in all of Japan (crowding, however, may be a consideration). As a consequence of conversations with Kure Harbor authorities, Area D of Figures V-35 and V-37 is recommended for large vessels, including supertankers and naval combatants. Smaller vessels normally remain pierside or utilize the protection found in the various coves around the harbor.

For those ships in port at Iwakuni the recommended procedure is to move to one of the designated typhoon anchorages, either Area A or C or D (in Kure) as seen in Figures V-35 and V-37.

Ship commanders should utilize the tropical cyclone warnings issued by FWC/JTWC, Guam in conjunction with Figures V-49 to V-53 to insure a timely shift to the typhoon anchorages. Ship commanders should also determine from the warnings whether the storm is forecast to pass west of Hiroshima Bay or east of the bay. Area A should provide excellent protection with storm passage to the west and very good coverage for storms passing to the south and east. Area C should provide excellent protection from storms which pass to the east.

4.3.4 Evasion At Sea

Evasion at sea is not the recommended course of action. However, if it is desired, an evasion route to sea may be developed by the use of the FWC/JTWC warnings, Appendix I-A and Figures V-49 to V-53 of this report. In all cases, however, Optimum Track Ship Routing (OTSR) should be consulted as to the best evasion route.

There are two basic evasion tactics for ships at sea south of Japan. The most common is to place the ship south of the tropical cyclone in the left or navigable semicircle. The other is to proceed southeast or east to remain clear of the tropical cyclone track.

If a ship is in the area south of Japan and the decision is made to seek refuge in Iwakuni or Kure, then the time enroute through the Bongo Straits into Hiroshima Bay (see Figure V-34) should be considered. At speeds of 10-12 kt, an enroute time of 10-12 hours could be expected upon entering the Bongo Straits.

Another option for ships south of Japan desiring refuge in a port would be the consideration of Yokosuka, Japan -- a designated safe typhoon "haven."

For a ship in the Sea of Japan or the Korean Straits, there are also two basic evasion tactics. The most common is to place the ship in the left or navigable semicircle of the tropical cyclone. The other is to proceed further north in the Sea of Japan or north into the Yellow Sea.

In the latter case, the cooler surface water and cool air found at higher latitudes cause a weakening and ultimate dissipation of the tropical cyclone. The central winds of tropical cyclones north of 35N are generally below 64 kt. Therefore, a ship would experience less difficulty in riding out a storm at these latitudes than if it steamed south to seek the navigable semicircle and encountered winds in excess of 80 kt enroute.

If refuge in port is desired, Sasebo, Japan, a designated typhoon "haven" (for all ships except aircraft carriers) would be more easily accessible to ships in the Sea of Japan or Korean Strait, than Iwakuni or Kure.

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SUMMARY

The conclusion reached by this study is that Sasebo Harbor is a favorable typhoon haven for all ships except aircraft carriers. This conclusion is based on the following reasons:

1. The harbor topography provides excellent protection from winds out of the north or east and good protection from southerly winds. However, due to the large "sail area" of a carrier, winds may affect the ship severely.

2. The anchor holding capability in the typhoon anchorage is excellent.

3. There is sufficient maneuvering room at typhoon anchorages in the outer harbor. However, aircraft carriers may be too restricted if many ships are present.

4. The inner harbor provides little protection for aircraft carriers. Ships of the size of AR's, AOE's, and AF's can find good protection at India Basin, Berths 8 and 9. Small ships have excellent protection in wet drydocks.

5. Surge effect is, in most cases, minimal and wave action in the past has not been too severe during the passage of a typhoon.

6. Port services available are excellent.

5.1 GEOGRAPHICAL LOCATION

Sasebo is located on the southern shore of the northwestern tip of Kyushu. The Kyushu mountains extend from north to south through the center of the island (see Figure V-54). The topography of the northwestern tip of Kyushu is depicted in Figure V-55. A detailed study of the coast and harbors of Kyushu is included in H. O. Publication 156, Sailing Directions (Enroute) for Japan.

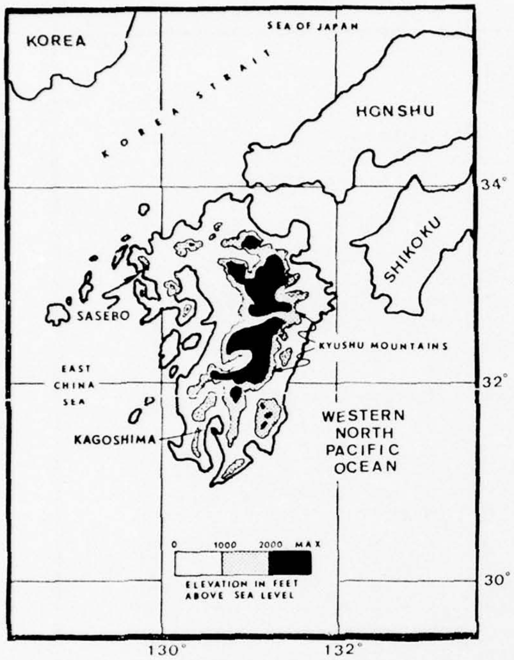

Figure V-54. Kyushu topography.

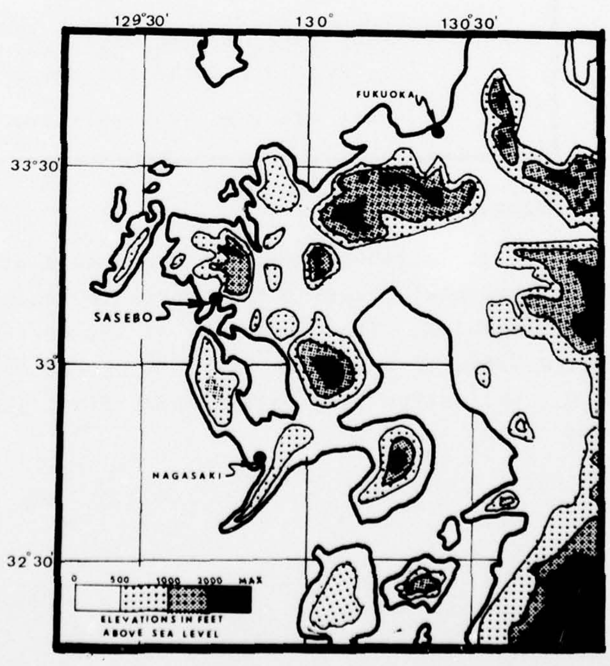

Figure V-55. Topography of the northwestern tip of Kyushu.

5.2. SASEBO HARBOR

The port of Sasebo, located at 33° 10'N, 129° 43'E, is one of the two major Japanese ports frequented by U. S. Navy ships. The port was established as a naval base in 1886. Prior to and during World War II it was an important repair base and, since the war, it has become a major commercial and shipbuilding port.

The inner harbor of the port is the northern extension of the outer harbor (see Figure V-56). The channel depth at the main entrance to the bay is over 110 ft, while the channel leading to the inner harbor is over 40 ft deep. The current flows at a maximum speed of 1.5 kt in the vicinity of the harbor entrance during a rising tide. The speed of current is faster during an ebb tide, but the current within the port limits is not so strong as to hinder navigation. There is no record of a tsunami (tidal wave) affecting the harbor.

Figure V-56 shows the location of India Basin in the inner harbor where Commander Service Group Three is located and Figure V-57 provides a close-up photograph of India Basin. This basin is used by large vessels, while Juliet Basin is utilized by harbor craft. The area between India and Juliet basins, known as "Tategami" is the resting place of about 15 mothballed LST's. During the passage of a severe typhoon close to Sasebo, these vessels provide a potential danger to other ships since they could break loose. This problem is recognized by the Operations Department of Fleet Activities and the vessels are therefore checked periodically.

The outer harbor provides numerous anchorages in a seabed with excellent holding strength. Typhoon anchorages are located in the vicinity of Ebisu Bay where protection is offered by the surrounding hills of Hario Island.

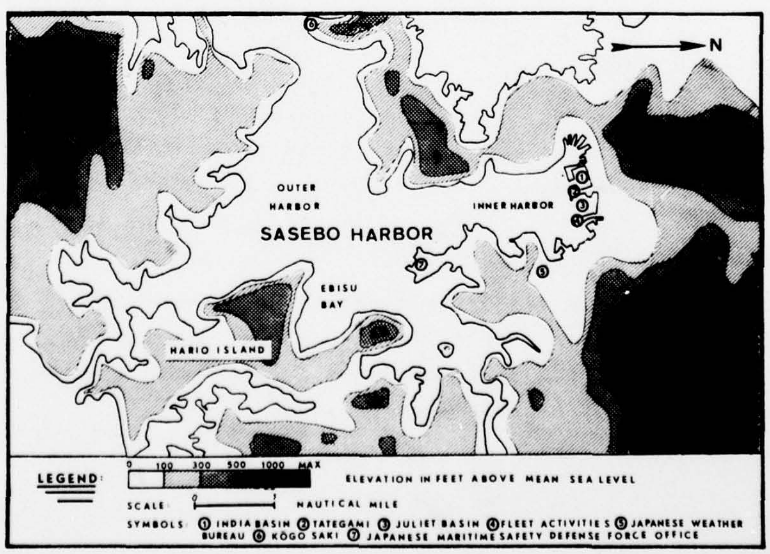

Figure V-56. Sasebo Harbor and surrounding topography.

SASEBO

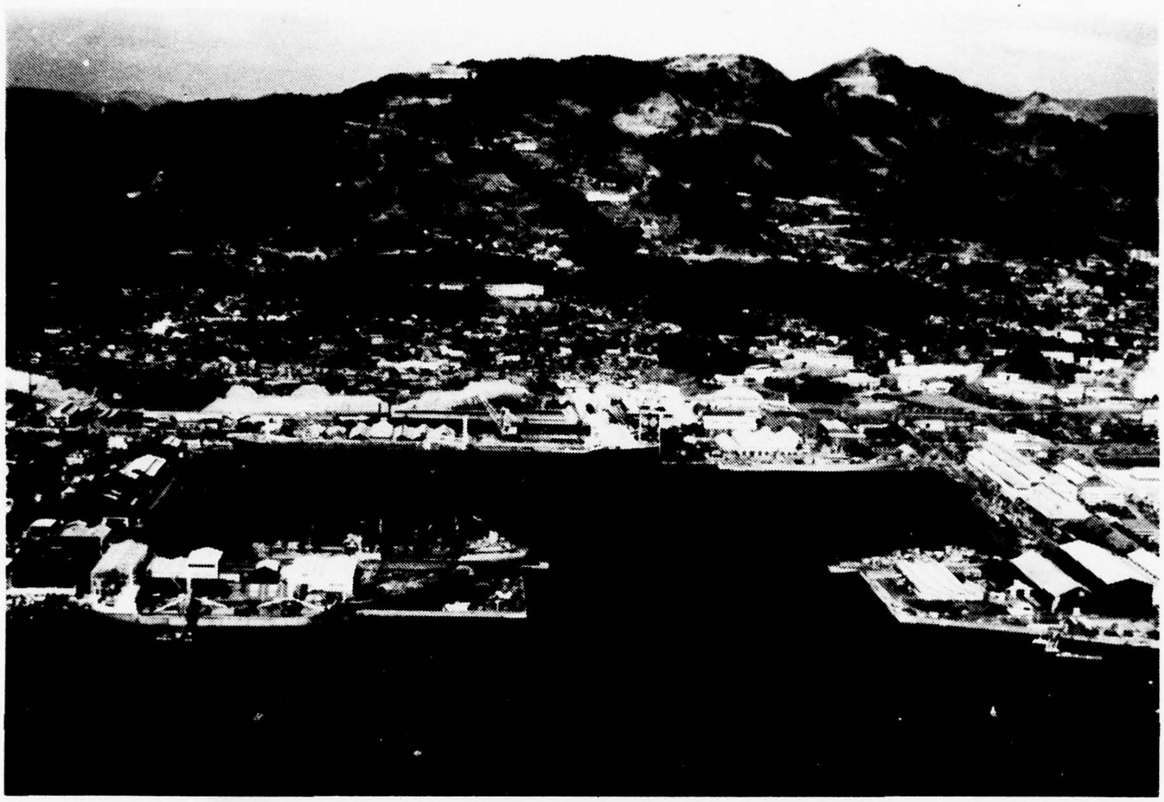

Figure V-57. Close-up view of India Basin located at northern part of Sasebo inner harbor looking north.

5.3 TOPOGRAPHY

Sasebo Harbor is a large land-locked bay , well protected by hills and mountains on all sides. This is particularly true for the inner harbor region (see Figure V-56).

5.4 HARBOR FACILITIES

India Basin can berth approximately eight large ships alongside. In addition, there are seven fueling piers, numerous mooring buoys with capacities up to 30,000 tons, and anchorages available in the bay. Major hull and machinery repair work can also be accomplished.

5.5 TROPICAL CYCLONES AFFECTING SASEBO

5.5.1 Tropical Cyclone Climatology For Sasebo

Climatology indicates that the island of Kyushu has been affected by tropical cyclones from April through December. However, the majority of the severe tropical cyclones that pose a threat to Sasebo (any tropical cyclone approaching within 180 n mi is considered a "threat") occur during the months of June-October.

Figure V-58 gives a monthly summary by 5-day periods of "threat" tropical cyclones. Seventy-three tropical cyclones threatened Sasebo during the 27-year period, June-October 1947-1973 (an average of 2.7 per year). The peak threat period is August, followed by July and September. Sixty-eight percent of the "threat" tropical cyclones had a northeasterly direction of movement prior to their closest point of approach (CPA) to Sasebo and, therefore, can be classified as "recurvers." Figure V-58 also indicates that during June and October, 100% of the "threat" tropical cyclones were "recurvers," followed by September (87%), August (65 %) and July (29%). Since the majority of "threat" tropical cyclones are recurvers, the reader may find it worthwhile to review the characteristics of recurving tropical cyclones (see paragraph 3, Chapter I).

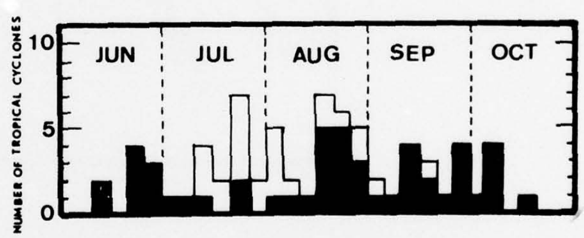

Figure V-58. Frequency distribution of the number of tropical cyclones that passed within 180 n mi of Sasebo. Subtotals are based on 5-day periods, for tropical cyclones that occurred during 1947-1973. Shaded area indicates the number of recurving tropical cyclones per 5-day period,

Table V-13 indicates that, of the 73 "threat" tropical cyclones during the years 1947-1973, 57% passed Sasebo to the east, 37% passed Sasebo to the west and 6% dissipated southwest of Sasebo. The fact that the majority of "threat" tropical cyclones pass to the east, implies that Sasebo is placed more often in the left or "navigable" semicircle where the wind and seas are less intense.

Table V-13. "Threat" tropical cyclone passage relative to Sasebo (1947-1973).

TRACK RELATIVE TO SASEBO	JUN	JUL	AUG	SEP	OCT	TOTAL
Passed east of Sasebo	6	6	14	11	5	42
Passed west of Sasebo	3	8	11	4	1	27
Dissipated without passing	0	3	1	0	0	4

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Figure V-59 displays the "threat" tropical cyclones according to the compass octant from which they entered the 180 n mi radius threat area. The circled numbers indicate the total that entered from an individual octant. The adjacent numbers express this as a percentage. It is evident that the majority of tropical cyclones (66%) entered the threat area from a sector extending from SW to SE.

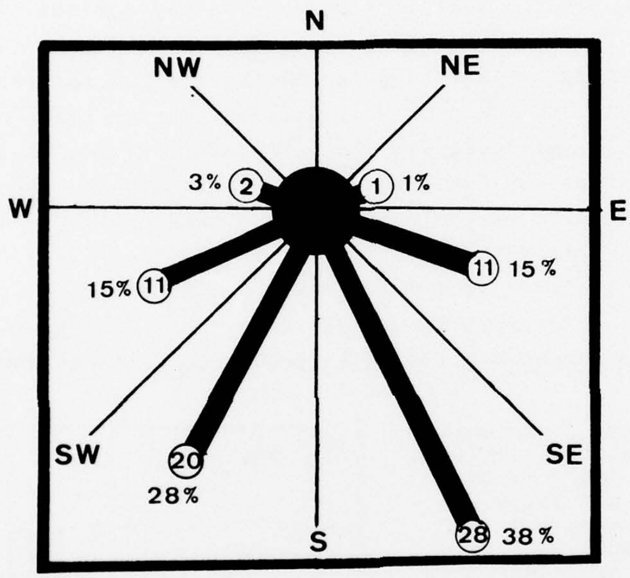

Figure V-59. Directions from which tropical cyclones entered threat area (a 180 n mi radius circle centered at Sasebo) during the period June-October, 1947-1973. Numbers circled indicate the number of tropical cyclones that entered from each octant. This is expressed as a percentage adjacent to the circled number.

Figures V-60 to V-64 present the percentage of tropical cyclones that have passed within 180 n mi of Sasebo (can be interpreted as the probability of threat) for the months June through October. The solid lines represent the "percent threat" for any storm location. The dashed lines represent approximate approach times to Sasebo, computed from the average tropical cyclone speed of movement for June-October (speeds of movement were derived from NWSED, Asheville, 1973). The average speeds are presented in Table V-14. For example, in Figure V-60, a storm located at 123E and 26N has a 60% probability of passing within 180 n mi of Sasebo, and it could reach Sasebo in 1-1/2 to 2 days.

Table V-14. Average speed of movement (kt) per 5-degree latitude for tropical cyclones affecting Sasebo for June-October.

LATITUDE	JUN	JUL	AUG	SEP	OCT	AVG
30N-35N	25	13	13	18	18	17.4
25N-30N	18	12	10	14	15	13.8
20N-25N	11	11	10	12	13	11.4
15N-20N	10	10	10	11	11	10.4

Note the significant shift in direction from which "threat" tropical cyclones approach Sasebo (Figures V-60 to V-64). In June, the "threat" is generally from the south to south-southwest; whereas, in Jul it is from the southeast. During August, the "threat" sector extends from south-southeast and then becomes more southerly in September and October.

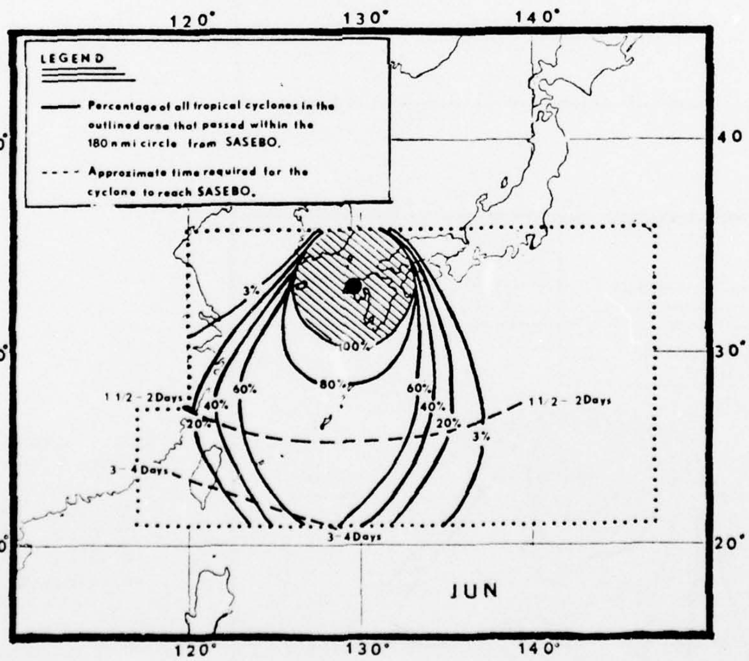

Figure V-60. Probability that a tropical cyclone will pass within 180 n mi of Sasebo (shaded area) for the month of June. (Based on data from 1947-1973.)

SASEBO

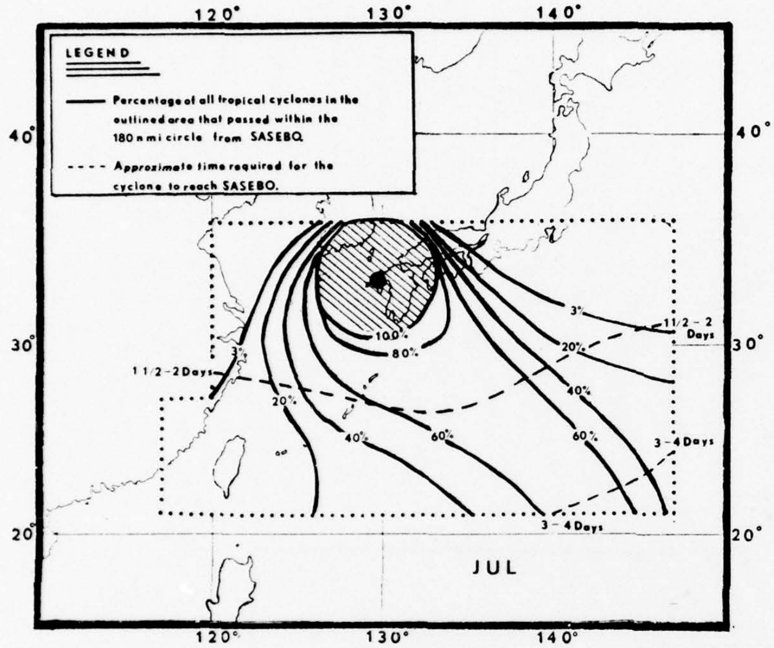

Figure V-61. Probability that a tropical cyclone will pass within 180 n mi of Sasebo (shaded area) for the month of July. (Based on data from 1947-1973.)

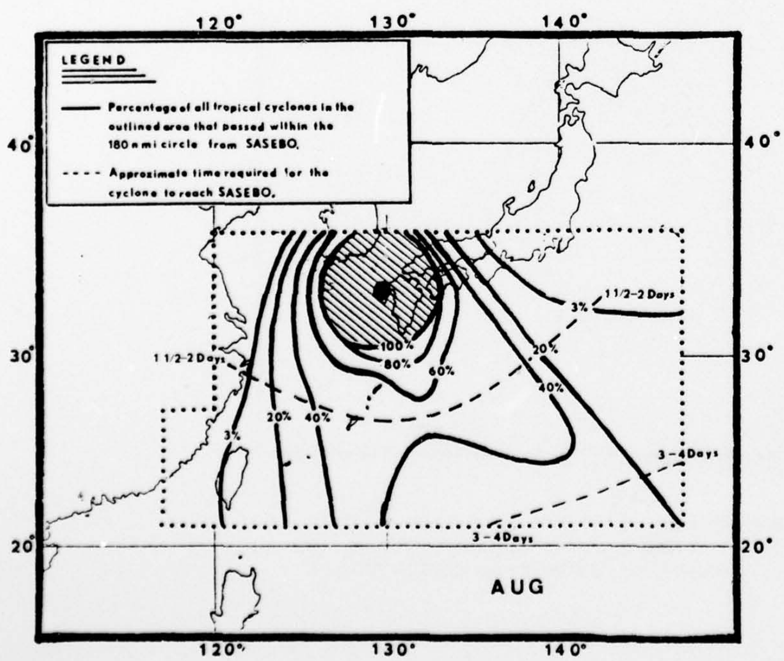

Figure V-62. Probability that a tropical cyclone will pass within 180 n mi of Sasebo (shaded area) for the month of August. (Based on data from 1947-1973.)

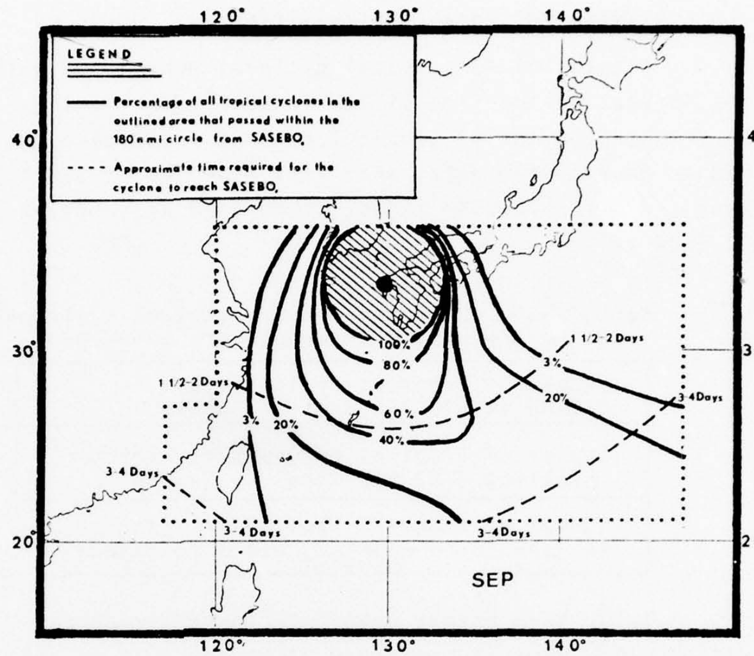

Figure V-63. Probability that a tropical cyclone will pass within 180 n mi of Sasebo (shaded area) for the month of September. (Based on data from 1947-1973.)

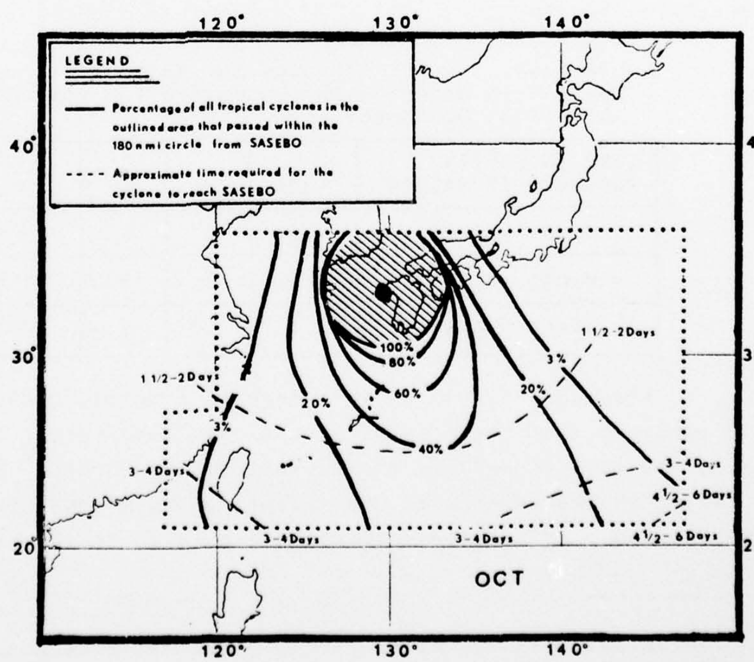

Figure V-64. Probability that a tropical cyclone will pass within 180 n mi of Sasebo (shaded area) for the month of October. (Based on data from 1947-1973.)

5.5.2 Wind And Topographical Effect

A total of 43 tropical cyclones approached within 180 n mi of Sasebo in the 15-year period from 1959-1973 during the months June-October.[14] Table V-15 groups the 43 tropical cyclones according to the wind intensity (based on hourly wind data) that they produced at Sasebo. Of the 43 tropical cyclones, 63% resulted in strong winds (≥22 kt) and 35% resulted in gale force winds (≥34 kt).

Table V-15. Extent to which tropical cyclones affected Sasebo during the period June-October, 1959-1973.

Number of tropical cyclones that passed within 180 n mi of Sasebo	43
Number of tropical cyclones resulting in strong (≥22 kt) winds in Sasebo	27 (63%)
Number of tropical cyclones resulting in gale force (≥34 kt) winds in Sasebo	15 (35%)

Table V-16 breaks down the "threat" tropical cyclones by month and resulting wind intensity recorded at Sasebo. It is interesting to note that in September, out of 7 tropical cyclones, 6 produced winds of gale force strength; whereas, in August only 8 out of 15 tropical cyclones produced winds of the same intensity at Sasebo.

Table V-16. Extent to which the 43 tropical cyclones from Table V-15 affected Sasebo during the period, June-October, 1959-1973, by month.

WIND INTENSITY PRODUCED AT SASEBO	JUN	JUL	AUG	SEP	OCT	TOTAL
Winds <22 kt	2	6	5	2	1	16
Winds ≥22 kt	2	2	15	7	1	27
Winds ≥34 kt	1	0	8	6	0	15

From an analysis of the "threat" tropical cyclones that affect Sasebo it is apparent that those tropical cyclones that result in gales at Sasebo can pass to the east as well as to the west of the harbor. This difference is the key factor in determining to what extent an individual tropical cyclone will affect Sasebo. If the tropical cyclone path is to the east across Kyushu, the

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[14]From Chin (1972) for years 1959-1970 and from Annual Typhoon Reports for years 1971-1973 (FWC/JTWC, 1971-1973).

tropical cyclone will lose some of its intensity through interaction with the land. In addition, the Kyushu mountains and local topography (see Figures V-54 and V-55) will provide protection from the winds of the tropical cyclone. An example of this was Typhoon Bess (August, 1963) with a CPA of 75 n mi to the northeast). The following conclusions were reached concerning this storm.

1. All U. S. naval vessels considered Sasebo Harbor a safe typhoon haven during the passage of Typhoon Bess east of Sasebo. No damage was reported by any of these ships.

2. Winds reported by ships in the harbor (maximum of 48 kt) tended to be higher than those reported by land based units. Ships in the southern part of the harbor at typhoon anchorage reported winds near the maximum, while ships in the northern part of the harbor reported winds close to 40 kt.

3. The use of a second anchor dropped under foot to reduce yawing and steaming to the anchor/mooring buoy to reduce the strain on the chain are highly recommended.

4. The wet drydocks provide excellent shelter for smaller ships.

In the case of a tropical cyclone passing west of Sasebo, the path is primarily over water. It is evident that the protection offered by topography to the south and west is much less than to the north and east of Sasebo. In addition, tropical cyclone passage to the west places Sasebo in the "dangerous" or right semicircle thus subjecting the harbor to higher wind velocities. An example of this case was Typhoon Gilda (July, 1974). The CPA of Typhoon Gilda was to the west at approximately the same distance (75 n mi) as Typhoon Bess and both typhoons had center winds of about the same intensity. However, Typhoon Gilda produced winds of 45 kt at Sasebo; whereas, Typhoon Bess resulted in winds of 38 kt at Sasebo. The following conclusions can be reached for this storm:

1. U.S. Naval vessels involved considered Sasebo Harbor as a safe typhoon haven during Typhoon Gilda's passage west of Sasebo.

2. India Basin, berths 8 and 9, can be used as a shelter from a typhoon passing to the west of Sasebo. Figure V-57 indicates that some shelter from southerly winds is provided by the building just to the south of berth 9. Maximum seas reported in India Basin during Gilda's passage were 5 ft confused.

3. All radars should be used under conditions of restricted visibility to obtain accurate fixes.

SASEBO

It must be pointed out that all of the wind data evaluations are based on the assumption that the "threat" tropical cyclone was solely responsible for the winds produced at Sasebo. This assumption does not take into account other extratropical synoptic features existing at the time which could "bias" the winds observed in Sasebo.

Since all of the hourly wind data analyzed during the 15-year period 1959-1973 was provided by the Japanese Weather Bureau, anotner "bias" in the wind data must be pointed out. Figure V-56 indicates the presence of a hill south of the Japanese Weather Bureau. Since the anemometer of the station does not extend above this hill, southerly winds recorded at the Japanese Weather Bureau will be less than actual winds experienced by ships in the harbor.

Figure V-65 shows the positions of "threat" tropical cyclone centers when strong winds (≥22 kt) were first and last recorded at Sasebo. It is apparent that "threat" tropical cyclones, as far away as 360 n mi, may produce winds ≥22 kt in Sasebo.

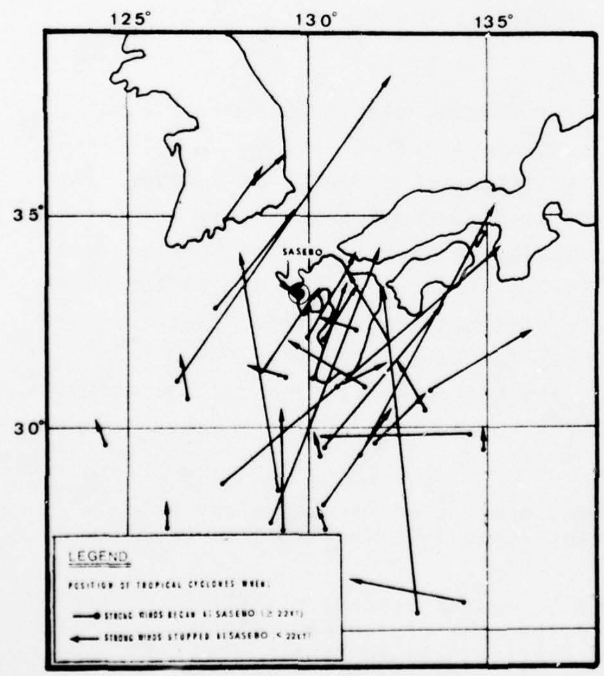

Figure V-65. Positions of tropical cyclone centers when winds greater than or equal to 22 kt first and last occurred at Sasebo. (Based on June-October data from the years 1959-1973.)

Figure V-66 shows tropical cyclone center positions when gale force (≥34 kt) winds were first and last recorded at Sasebo. It can be seen that winds ≥34 kt generally exist with storms within 200 n mi of Sasebo. Notice the large number of tropical cyclone occurrences to the south and east of Sasebo that produced strong or gale force winds at the Japanese Weather Bureau.

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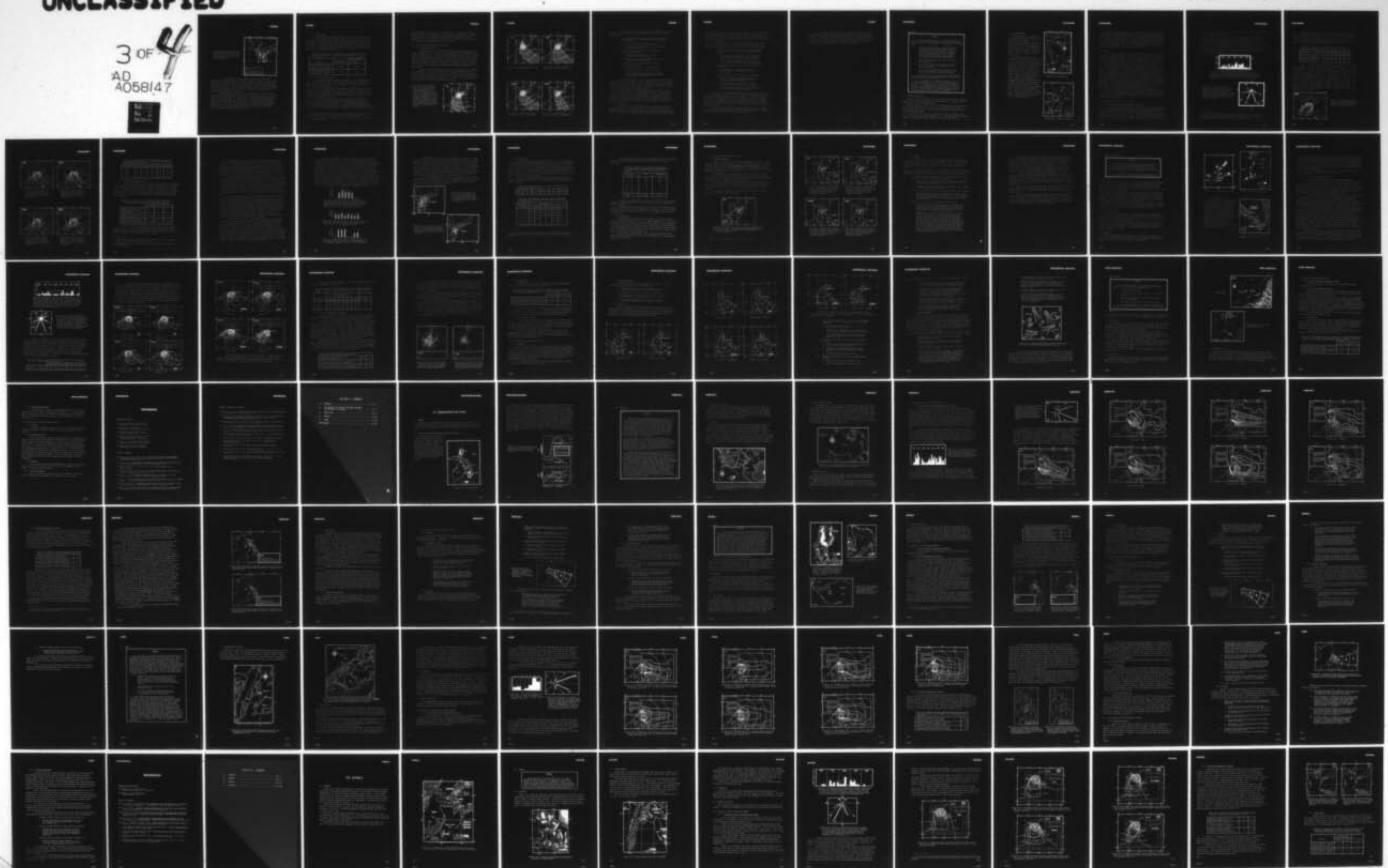

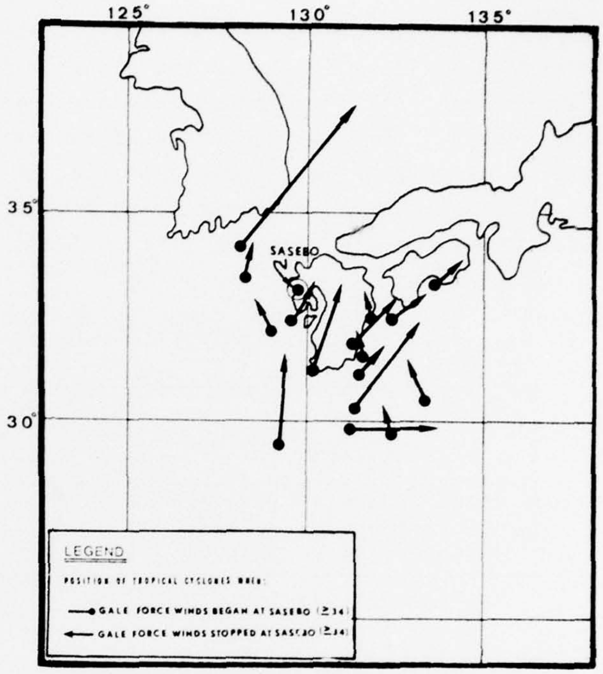

Figure V-66. Positions of tropical cyclone centers when winds greater than or equal to 34 kt first and last occurred at Sasebo. (Based on June-October data from the years 1959-1973.)

In analyzing Figures V-65 and V-66, one must keep in mind the following: (1) a greater number of "threat" tropical cyclones will pass to the east of Sasebo (approximately 60% to the east, 40% to the west; see Table V-13; and (2) the fact that a "bias" is associated with the wind observations used in this analysis (that is, southerly winds associated with tropical cyclone passage to the west are not as readily detected as northerly winds associated with tropical cyclone passage to the east).

The most severe threat to the harbor occurs when a tropical cyclone approaches from the southwest and passes west of Sasebo within 50 n mi. In this case, the elevations of Hario Island serve as a good wind barrier for ships at typhoon anchorage at Ebisu Bay. When tropical cyclones pass to the east of Sasebo, the elevations to the north and east of the harbor provide excellent protection. In this case, maximum winds can be expected from the north (see Figure V-56). For a more complete description of the effects of tropical cyclones on Sasebo Harbor, see Rudolph, 1975.

5.5.3 Wave Action

Maximum wave action is associated with a typhoon passing to the west since this places Sasebo in the right or "dangerous" semicircle of the typhoon. The greater relative wind in this area generates waves which tend to be more destructive. Because the shape of the harbor reduces the fetch, and because of the relatively narrow harbor entrance, the effects of the typhoon related sea is minimized. The maximum wave heights that can be expected with typhoon strength winds ($\geq$64 kt) are given in Table V-17.[15]

Table V-17. Maximum wave heights that can be expected with typhoon strength winds ($\geq$64 kt) in vicinity of India Basin and typhoon anchorage.

SITUATION	AREA JUST SOUTH OF INDIA BASIN	TYPHOON ANCHORAGE (VICINITY OF EBISU BAY)
Winds generally from the north (tropical cyclone passage east of Sasebo)	4 feet	8 feet
Winds generally from the south (tropical cyclone passage west of Sasebo)	7 feet	5 feet

5.5.4 Storm Surge And Tides

When a tropical cyclone crosses a coastline a rise in water level may occur. This is caused by wind stress on the water surface and the effects of atmospheric pressure reduction. Also, tides may act to either increase or decrease this rise in water level.

The storm surge effect is most evident in the shallow waters of large inland bays open to the south coast of Japan.[16] The height of the storm surge in a given port is dependent on the tropical cyclone track. If the track is to the west of the port, the peak surge will be large; while the opposite is true for a track to the east of the port.

Of 10 tropical cyclones which passed to the west of Sasebo over a 5-year period, the maximum tidal height over the normal tide was 1.3 feet. Since the tidal range for Sasebo Harbor is 10 to 12 feet, this relatively small storm surge would be significant only if it coincided with a high spring tide and large waves. These three factors did coincide in July 1974 with the passage

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[15] Based on forecasting curves for shallow-water waves from U.S. Army Coastal Engineering Research Center, 1973: "Shore Protection Manual (Volume I)."

[16] Miyazaki, M., 1974: "Characteristics of Storm Surges Induced by Typhoons along the Japanese Coast."

of Typhoon Gilda (CPA of 75 n mi to west-northwest). Large amounts of water were forced over the southern walls in both Juliet and India Basins. However, even under these extreme conditions, India Basin was considered a "safe, adequate haven" by the commanding officer of USS SACRAMENTO (AOE-1) berthed at India Nos. 7 and 8 during Typhoon Gilda's passage.

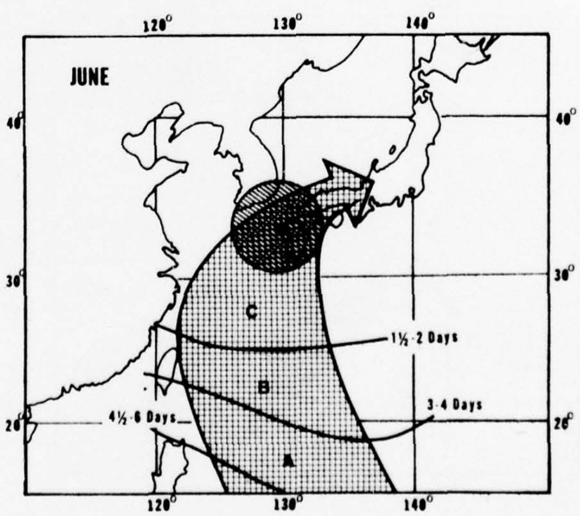
5.6 THE DECISION TO EVADE OR REMAIN IN PORT

5.6.1 Remaining In Port

Remaining in port is the recommended course of action for all ships except aircraft carriers. Commander Service Group THREE in SOPA (ADMIN) Sasebo Instruction 5000.1 series makes the following statements pertinent to the use of Sasebo as a typhoon haven: "Because of local topography, Sasebo Harbor provides excellent shelter during the passage of a typhoon to the east, and good shelter during the passage of a typhoon directly over or close to the west. Mooring buoy capacities and suitability of anchorages are adequate. Generally speaking, Sasebo Harbor can be considered a typhoon haven for all but the largest of naval ships."

Figures V-67 to V-71 show the tropical cyclone threat axis for Sasebo from June-October. The cross-hatched area of the arrow represents a 30% or greater probability of a tropical cyclone coming within 180 n mi (indicated by the hatched circle) of Sasebo. In addition, an effort has been made to indicate the most frequent direction of passage, east or west of Sasebo, by displacing the center of the arrow in the corresponding direction.

Figure V-67. Tropical cyclone threat axis for the month of June. The area within the arrow approximates a 30% or greater probability of a tropical cyclone coming within 180 n mi of Sasebo (hatched area). Displacement of the arrowhead center east or west of Sasebo indicates a greater tendency for tropical cyclone passage on the corresponding side. Approach times to Sasebo are based on typical speeds of tropical cyclones affecting Sasebo.



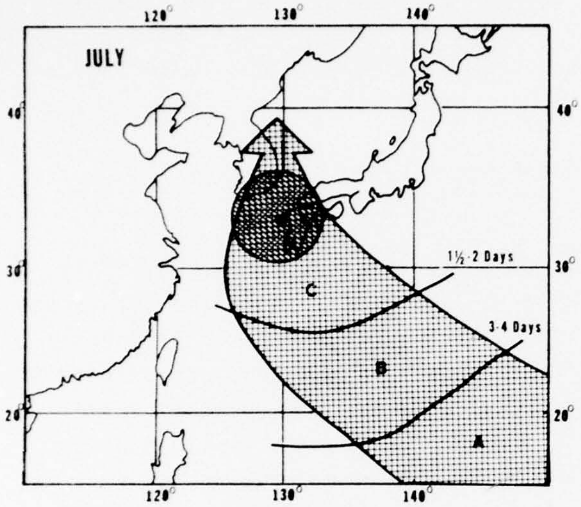


Figure V-68. Tropical cyclone threat axis for the month of JULY.

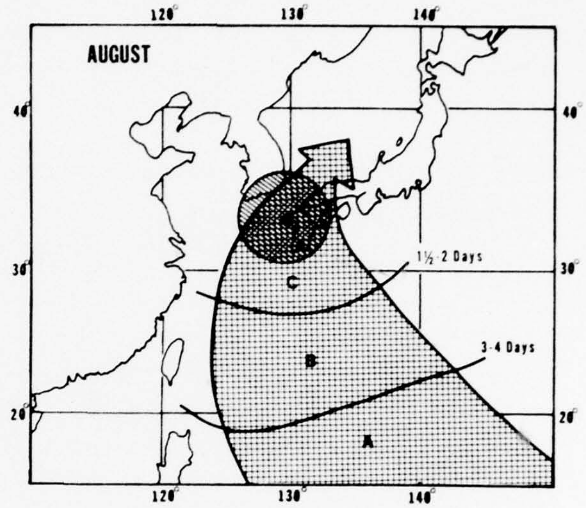


Figure V-69. Tropical cyclone threat axis for the month of AUGUST.

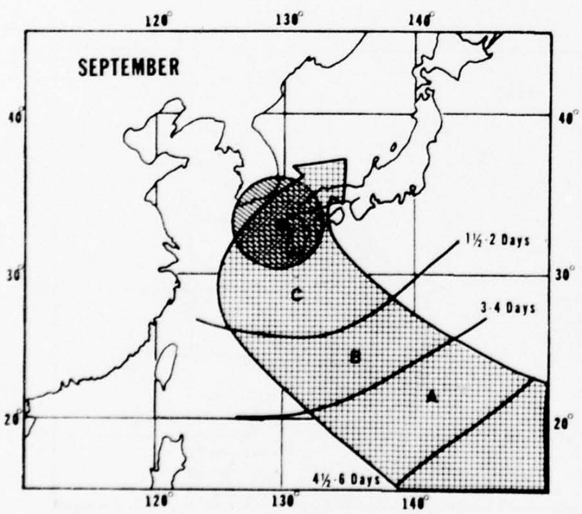


Figure V-70. Tropical cyclone threat axis for the month of SEPTEMBER.

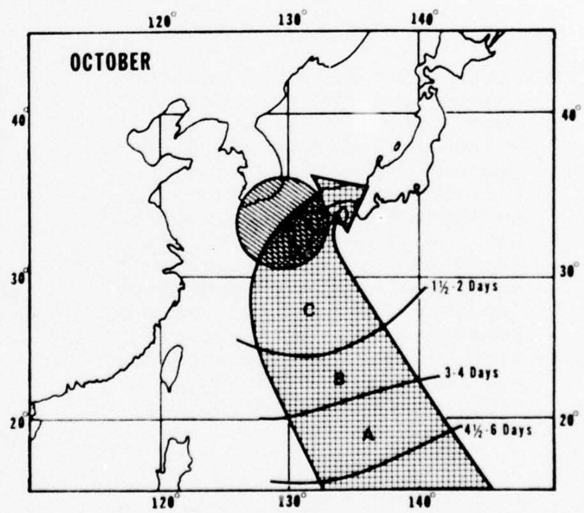


Figure V-71. Tropical cyclone threat axis for the month of OCTOBER.

To correctly assess the threat posed by an approaching tropical cyclone, the following timetable incorporating Figures V-67 to V-71 was constructed:

1. An existing tropical cyclone moves into or potential development occurs in Area A with forecast movement toward Kyushu:

   a. Review the material condition of the ship.

   b. Reconsider all maintenance activities scheduled to exceed 48 hours.

2. A tropical cyclone enters Area B with forecast movement toward Sasebo:

   a. Reconsider all maintenance activities scheduled to exceed 24 hours.

   b. Prepare ship for heavy weather and be ready for movement to typhoon anchorage.

3. A tropical cyclone enters Area C with forecast movement toward Sasebo:

   a. Be prepared to move to typhoon anchorage.

   b. Review availability of tugs and pusherboats.

   c. Ensure sufficient power available to counter high winds and seas by steaming to the anchor (see paragraph 5, Chapter I).

Even though utilization of the typhoon anchorages in the southern part of the harbor is preferred, several commanding officers have noted that India Basin, especially berths 8 and 9, is suitable for larger ships during the passage of a typhoon. Wet drydocks to the west of India Basin provide excellent shelter for small ships (MSC, ATF, etc.).

There have been only a few incidences where ships have incurred damage from a typhoon while in Sasebo and generally this resulted from ships parting their moorings due to shackle failure. The use of "oversized" or doubled-up" shackles and steaming to the buoy are recommended. Another possible problem during the passage of a typhoon is that the mothballed LST's moored at Tategami could break loose and present a hazard to other ships.

5.6.2 Evasion

Evasion at sea is recommended only for aircraft carriers for the following reasons: (1) typhoon anchorages may be too restrictive for an aircraft carrier if many ships are present, (2) the effect of typhoon related winds is intensified by the carriers large "sail area," (3) suitable berthing

is not available in the inner harbor for an aircraft carrier, and (4) there are no records available of a large, modern aircraft carrier remaining in Sasebo Harbor during the passage of a typhoon; however, past experience has proven Sasebo Harbor to be a typhoon haven for ships smaller than an aircraft carrier (AR, AF, etc.).

Since the waters near Sasebo Harbor are restricted, evasion for carriers must commence early. To facilitate early action, the following timetable (in conjunction with Figures V-67 to V-71 has been constructed:

1. An existing tropical cyclone moves into or development takes place in Area A with forecast movement toward Kyushu:

   a. Review material condition of ship. A sortie may be desirable 2-4 days hence. Begin planning course of action to be taken in case of sortie.

   b. Reconsider any maintenance that would render the ship incapable of getting underway within 48 hours.

2. Tropical cyclone enters Area B with forecast movement toward Sasebo:

   a. Execute sortie plans made in previous steps. Sortie should be completed before storm enters Area C.

3. Tropical cyclone enters Area C moving toward Sasebo.

   a. If sortie was not accomplished by this time evasion is no longer recommended. Prepare to move to typhoon anchorage.

   b. Ensure sufficinet power available to counter high winds and seas by steaming to the anchor.

   c. Ensure a sufficient number of tugs are available to make the move to typhoon anchorage.

Evasion routes at sea may be developed by the use of the tropical cyclone warnings (see paragraphs 6 and 7 of Chapter I), and Appendix 1-A (the mean tropical cyclone tracks, track limits, and average speed of movements) for the month of interest in conjunction with Figures V-67 to V-71 (tropical cyclone threat axis and approach times to Sasebo for the months June-October). In all cases, Optimum Track Ship Routing (OTSR) should be consulted as to the best evasion route.

There are two basic evasion tactics. The most common is to place the ship south of the tropical cyclone in the navigable semicircle. The other is to proceed north into the Yellow Sea or Sea of Japan.

In the latter case, the cooler surface water and cool air found at higher latitudes cause a weakening and ultimate dissipation of the tropical cyclone. The central winds of tropical cyclones north of 35N are generally below 64 kt. Therefore, a ship would experience less difficulty in riding out a storm at these latitudes than if it steamed south to seek the navigable semicircle and encountered winds in excess of 80 kt enroute.

6. KAGOSHIMA

SUMMARY

The conclusion reached in this study is that Kagoshima Harbor is not a safe harbor during the passage of an intense tropical cyclone. The key factors in reaching this conclusion are:

1. Due to the size and shape of Kagoshima Bay and surrounding land masses, the harbor provides little shelter from wind and seas. (During the period 1947-74, the highest recorded wind gust in Kagoshima was 100 kt due to Typhoon Louise (29 September 1955). This typhoon passed 30 n mi to the west of Kagoshima and contributed 5 hours of gale force winds.)

2. Wave action induced by gale force winds can be quite dangerous.

3. The holding action of the bottom in the harbor area is considered very poor under adverse weather conditions.

4. The restricted nature of the anchorage itself would give a commanding officer little reaction time in the event the anchor began to drag.

This conclusion is in full agreement with the Kagoshima Harbor authorities and the Japanese Maritime Safety Agency concerning ships that are anchored.

It is recommended that commanding officers and masters of vessels take early evasion action commensurate with operational constraints. For U. S. Navy or contracted DOD vessels, it is recommended that Sasebo or Hiroshima Bay be given priority consideration as typhoon havens. If evasion at sea is more desirable, it is recommended that the ship be placed in the Yellow Sea or Sea of Japan where effects from the typhoon will be considerably lessened.

6.1 GEOGRAPHICAL LOCATION

Kagoshima Harbor is located on the western side in the northern region of Kagoshima Bay. The bay itself cuts into the southern tip of Kyushu Island for a distance of 45 n mi (see Figure V-54).

A dominant feature in the vicinity of Kagoshima Harbor is Sakurajima, an active volcano which rises out of the bay to a height of 3655 ft, about 2 n mi from the harbor facilities. Figure V-72 shows the general features of the region around Kagoshima Bay.

Also located in the vicinity is the largest crude oil terminal in the world at Kiire, 14 n mi south of Kagoshima City. This man-made facility handles in excess of 500 vessels a year with berths for 500,000 DWT tankers.

6.2 KAGOSHIMA HARBOR

Kagoshima Harbor is located at 31° 35'N, 130° 34'E and is one of the principal ports in Kyushu. It is primarily an exporting port for agricultural and light industrial products. Additionally, it is a terminal point for auto/ passenger ferry boats operating between Japan and Okinawa. On occasion, the U.S. Navy utilizes the city as a liberty port.

The harbor facilities in the Kagoshima port area consist of numerous "ports" that have been constructed to provide specialized services for various industries. These ports stretch southward from the central city area for approximately 10 n mi. Figure V-73 depicts some of these "ports" servicing Kagoshima City. It should be noted that as newer facilities are built or planned, they will be designed to accommodate the larger vessels that are currently being built. For example, at the newer port at Taniyama No. 2 (not shown), the south berth is approximately 4300 ft long with a design depth of 43 ft., while at an older port, Shinkoh Harbor further to the north, the longest berth is approximately 850 ft with a limiting depth of about 25 ft.

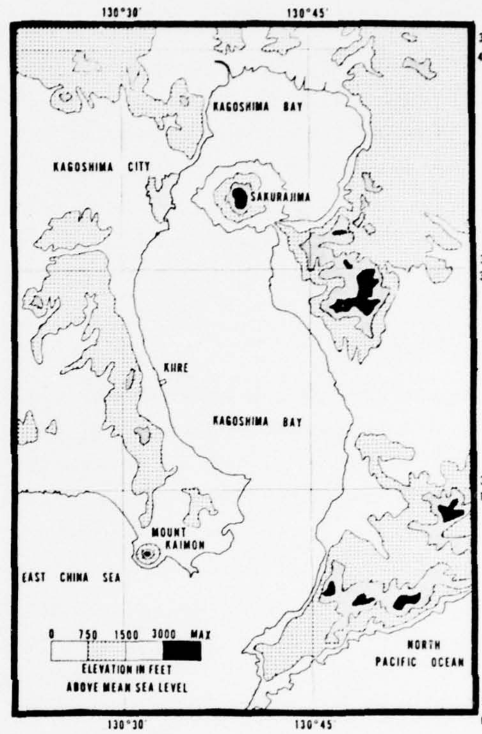


Figure V-72. Kagoshima Bay.

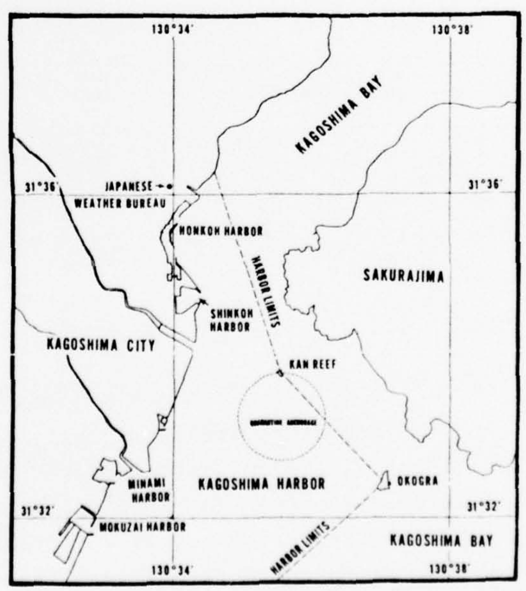


Figure V-73. Kagoshima Harbor.

Currents in the harbor area flow at a speed of about 2 kt when the tide is setting south in the area between Kagoshima City and Sakurajima. These currents result from rising and ebbing tides and are not considered hazardous to navigation. There is no known record of a tsunami ("tidal wave") affecting the harbor.

The outer harbor has numerous anchorages with poor holding strength (fine to coarse sand and shale). There are no safe typhoon anchorages in the area. (Refer to Port Directories of U. S. Pacific Fleet and Military Sealift Command for details on additional port and harbor facilities.)

6.3 TOPOGRAPHY

Kagoshima Bay is a large bay opening to the extreme southern tip of Kyushu. At its widest point, at about 31° 20'N, it is 12.5 n mi wide. The north-south distance is approximately 45 n mi. Except for Sakurajima, there are no other significant topographic features breaking the expanse of the bay itself. Figure V-72 shows the topographic features of Kagoshima Bay and its surroundings.

Sakurajima, an active volcano, is situated in the northern reaches of the bay. During the last significant eruption, it connected itself with the eastern shore of the bay. Current activity is limited to releasing considerable amounts of smoke and ash. It should be noted that this volcano and others on the island of Kyushu from time to time "rumble" as a reminder of their activeness. While Sakurajima does offer the harbor and anchorage protection from winds and rough seas generated by local weather conditions, it can also compound the adverse effects of heavy weather when the area comes under the influence of a tropical cyclone or other storms of equal size or intensity. Sakurajima and the mountains on the western side of the bay present a significant topographical feature that could influence northeasterly winds and produce a localized funneling and strengthening of the winds affecting the harbor area.

A mountain ridge that rises to 4080 ft lies along the eastern side of the bay. To the west of Kagoshima Bay is the aforementioned mountain ridge rising to nearly 2000 ft that gradually becomes rolling foothills and low lying areas to.the south with Mount Kaimon rising from the southern tip of Kyushu at the western entrance to the bay.

6.4 TROPICAL CYCLONES AFFECTING KAGOSHIMA

6.4.1 Tropical Cyclone Climatology For Kagoshima

Climatology indicates that the island of Kyushu has been affected by tropical cyclones from April through December. The majority, however, that pose a threat to Kagoshima (any tropical cyclone approaching within 180 n mi of Kagoshima Harbor is defined as a "threat" for the purpose of this study) occur during the months of June-October. Figure V-74 gives the frequency distribution during the months of "threat" occurrences by 5-day periods. This summary is

based on data for the 28-year period, 1947-1974. Note that the maximum number occur during August and September.[17]

Figure V-75 depicts, on an 8-point compass, the "threat" tropical cyclones according to the octant from which they approached Kagoshima. The circled numbers indicate the total that approached from an individual octant. The count for an octant of approach includes both recurving and non-recurving tropical cyclones. (See paragraphs 3 of Chapter I for a description of recurving tropical cyclones.) Note that a majority of these approach from the south-southeast and south-southwestern octants. A more detailed inspection of the 85 tracks revealed that 20 (22%) did not recurve prior to passing the closest point of approach to Kagoshima.

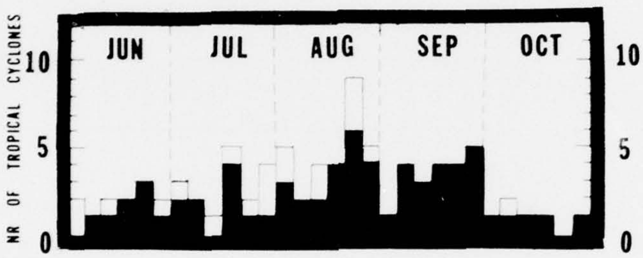
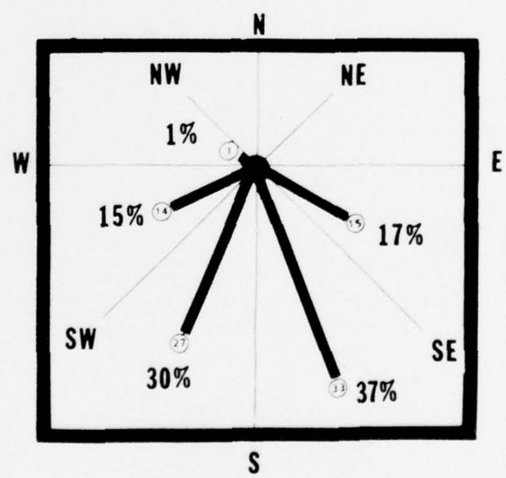


Figure V-74. Frequency of tropical cyclones that passed within 180 n mi of Kagoshima. Subtotals are based on 5-day periods for tropical cyclones that occurred during 1947-1974. Shaded area indicates recurving tropical cyclones per 5-day period (that is, had a northeasterly direction of motion at CPA).

Figure V-75. Directions from which tropical cyclones entered threat area (a 180 n mi radius circle centered at Kagoshima) during the period May-November, 1947-1974. Numbers circled indicate the number of tropical cyclones that entered from each octant. This is expressed as a percentage adjacent to the circled number.



[17] A total of 90 tropical cyclones passed within 180 n mi of Kagoshima during the May-November period for the years 1947-1974. Eighty-five (94%) of these tropical cyclones passed within 180 n mi during the 5 months June-October, and the remaining 5 passed in the months of May and November.

KAGOSHIMA

Table V-18 indicates that, of the 85 tropical cyclones that posed a threat to Kagoshima during the years 1947-1974 (June-October), 53% passed to the east of Kagoshima, 36% passed to the west and 11% passed in the immediate vicinity of the port. The fact that the majority of the "threat" tropical cyclones pass to the east, implies that Kagoshima is placed more often in the left or "navigable" semicircle where the wind and seas are less intense.

Table V-18. "Threat" tropical cyclone passage relative to Kagoshima (1947-1974).

TRACK RELATIVE TO KAGOSHIMA	JUN	JUL	AUG	SEP	OCT	TOTAL
Passed east of Kagoshima	5	10	10	15	5	45
Passed west of Kagoshima	7	7	13	3	1	31
Passed in the immediate vicinity of Kagoshima	0	0	6	3	0	9

Figures V-76 to V-80 represent an analysis of the estimated probability for any tropical cyclone approaching within 180 n mi of Kagoshima. The solid lines represent the probability of coming within 180 n mi of Kagoshima for any storm location. The dashed lines represent the approximate time in days for a system to reach Kagoshima, computed from typical speeds of movement for tropical cyclones affecting Kagoshima (Table V-19). For example, in Figure V-76, a tropical cyclone located at 25°N, 130°E has a 60% probability of passing within 180 n mi of Kagoshima and it will reach Kagoshima in about 1 1/2-2 days.

Note the significant shift in direction from which tropical cyclones approach the Kagoshima area (Figures V-76 to 80). In June the "threat" is generally from the southwest whereas, in July and August it is more to the south and southeast, then becomes more southerly in September, and then south to southwesterly in October.

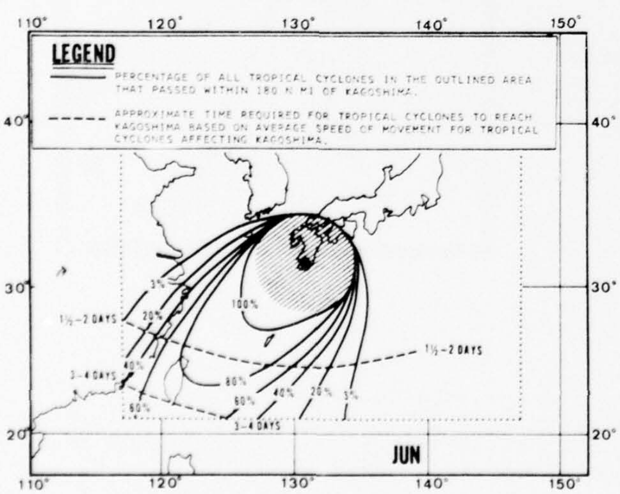


Figure V-76. Probability that a tropical cyclone will pass within 180 n mi of Kagoshima (shaded area) for the month of June. (Based on data from 1947-1974.)

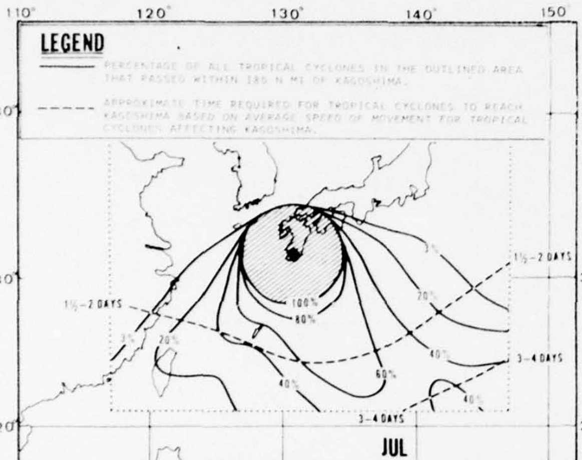


Figure V-77. Probability that a tropical cyclone will pass within 180 n mi of Kagoshima (shaded area) for the month of July. (Based on data from 1947-1974.)

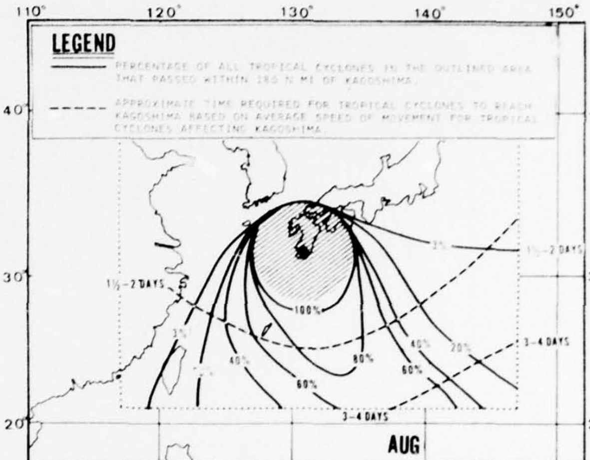


Figure V-78. Probability that a tropical cyclone will pass within 180 n mi of Kagoshima (shaded area) for the month of August. (Based on data from 1947-1974.)

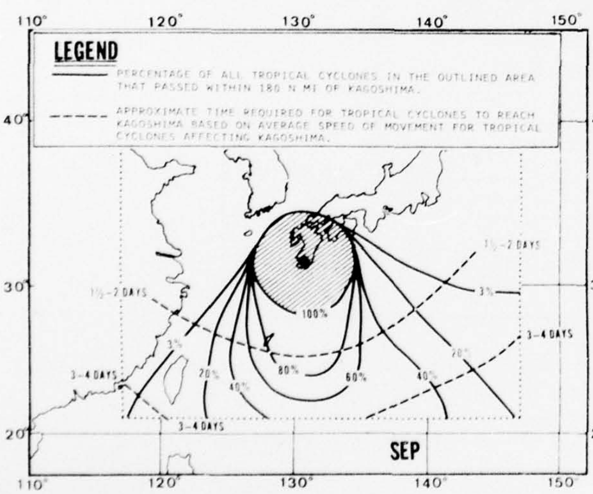


Figure V-79. Probability that a tropical cyclone will pass within 180 n mi of Kagoshima (shaded area) for the month of September. (Based on data from 1947-1974.)

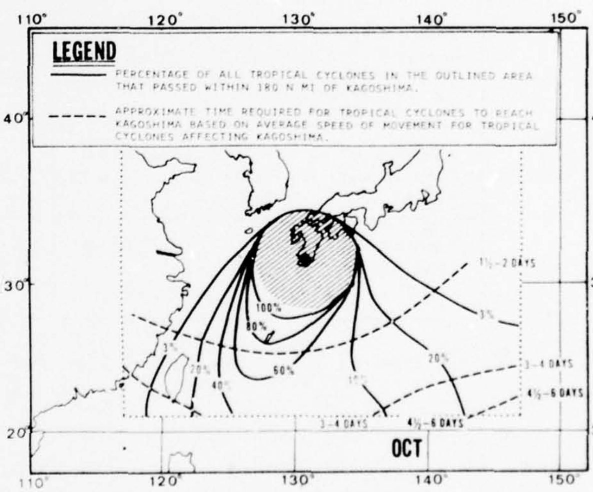


Figure V-80. Probability that a tropical cyclone will pass within 180 n mi of Kagoshima (shaded area) for the month of October. (Based on data from 1947-1974.)

Table V-19. Average tropical cyclone speed of movement (kt) per 5-degree latitude band for tropical cyclones affecting Kagoshima for June-October.

LATITUDE BAND	JUN	JUL	AUG	SEP	OCT	AVERAGE
30-35N	25	13	13	18	18	17.4
25-30	18	12	10	14	15	13.8
20-25	11	11	10	12	13	11.4
15-20	10	10	10	11	11	10.4

5.4.2 Wind And Topographic Effect

A total of 54 tropical cyclones approached within 180 n mi of Kagoshima in the 19-year period 1956-1974 during the months June-October,[18] or about 3.1 a year. Table V-20 groups the tropical cyclones by strong (≥22 kt) and gale force (≥34 kt) wind intensities (based on hourly wind data) that they produced at Kagoshima.[19] Tropical cyclone activity in the Kagoshima area is maximal during the months of August and September and these individual monthly values are also shown.

Table V-20. Extent to which tropical cyclones affected the Kagoshima area during the period June-October, 1956-1974, and for the individual months of August and September.

	JUN-OCT	AUG	SEP
Number of tropical cyclones that passed within 180 n mi of Kagoshima	54	22	13
Number of tropical cyclones resulting in strong (≥22 kt) winds at Kagoshima	43(80%)	16 (73%)	10 (77%)
Number of tropical cyclones resulting in gale force (≥34 kt) winds at Kagoshima	21 (39%)	10 (45%)	4 (31%)

It can be discerned from Table V-20 that 21 (39%) of the total 54 tropical cyclones for the period June-October (1956-1974) resulted in winds of 34 kt or greater at Kagoshima. However, of 22 tropical cyclones tracked in August, 10 (45%) resulted in winds of 34 kt or greater.

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[18] From Chin (1972) for years 1956-1970 and from Annual Typhoon Reports for years 1971-1974 (FWC/JTWC, Guam, 1971-1974).

[19] Data provided by the Japanese Meteorological Agency weather station located at Kagoshima.

An observation station for the Japanese Meteorological Agency is located in the downtown area of Kagoshima near the harbor facilities (see Figure V-73). The wind instrument is located on top of the station in such a manner as to be unobstructed from any nearby buildings or trees. During the period 1947-1974, the highest recorded wind gust in Kagoshima was 100 kt on 29 September 1955. This easterly gust was attributed to Typhoon Louise which passed 30 n mi to the west of Kagoshima on 29 September 1955. The duration of gale force wind (excess of 33 kt) was 5 hours during this storm.

Winds in Kagoshima Bay are significantly influenced by the surrounding topography and the geographical features of the bay itself. The extent of this influence is dependent on the direction of approach of the storm and the passage relative to the Kagoshima area. From an analysis of the tropical cyclones that affected Kagoshima it is apparent that tropical cyclones that result in gale force winds at Kagoshima can pass to the east or west of Kagoshima or in some instances the center of the storm passes over the immediate area. The basic difference in effect is the direction and strength of the resultant wind in the area.

If the tropical cyclone passes to the east of Kagoshima, the path will generally be over water and the winds will be primarily northeasterly. While there will be some interaction with the Kyushu Mountains (see Figure V-54) to decrease the intensity of the winds, local topography becomes significant in its effect on northeasterly winds. The mountains on the northwestern side of the bay that rise to nearly 2000 ft and Sakurajima which rises to 3655 ft tend to direct and funnel winds from the northeastern quadrant into the narrow region of the Kagoshima Harbor area as can be seen in Figures V-72 and V-73. An example of this was Typhoon Helen which had a CPA of 40 n mi to the east-southeast of Kagoshima on 24 September 1966. During this particular typhoon, wind gusts were recorded up to 78 kt from the northeast.

In the case of tropical cyclones passing to the west of Kagoshima, the path is also over water in its approach to the area, thus retaining much of its strength before striking Kyushu. From Figures V-54 and V-72 it is evident that the protection offered by surrounding topography is of little assistance in decreasing the intensity of the storm as it makes its first encounter with land. The long broad expanse of Kagoshima Bay allows practically uninterrupted flow from the southeastern quadrant. These factors, in addition to the bay being placed in the "dangerous" semicircle, makes a western passage extremely dangerous. An example of this case was Typhoon Babs which had a CPA of 150 n mi to the west-northwest of Kagoshima on 16 August 1956. Typhoon Babs produced wind gusts of up to 72 kt from the south-southeast.

KAGOSHIMA

Figures V-81 through V-83 show the average maximum wind gust associated with the tropical cyclones studied, and the direction from which it originated as recorded at Kagoshima during the period 1947-1974. An evaluation of these figures show that winds from tropical cyclones passing to the west come primarily from the southeasterly direction and tend to be more intense than those from tracks of storms passing to the east. In those cases, the winds may come from any direction but for the most part come from the northeast or northwest. Occasionally, a tropical cyclone will pass in the immediate vicinity of Kagoshima. In the period 1947-1974, ten such storms tracked in such a manner with all but one producing gale force winds or stronger. Under such circumstances, there is no discernible pattern as to prevailing direction from which the strongest winds originate. The proximity of the storm's center when passing in the immediate vicinity, however, is indicative of force. Of the 10 tropical cyclones studied, the average maximum wind gust was 58 kt.

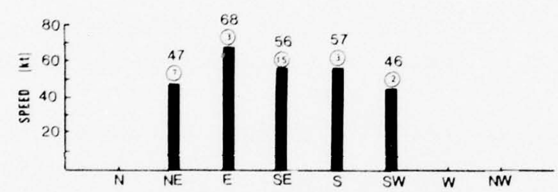

Figure V-81. Average maximum wind gust and direction of winds originating from tropical cyclones passing within 180 n mi to the west of Kagoshima. (Numbers circled indicate total number of tropical cyclones producing winds from the direction indicated.)

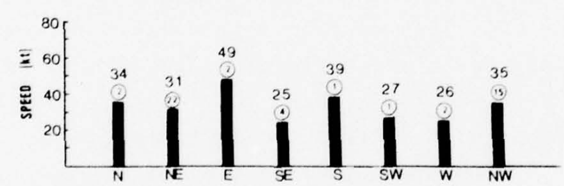

Figure V-82. Average maximum wind gust and direction of winds originating from tropical cyclones passing within 180 n mi to the east of Kagoshima.

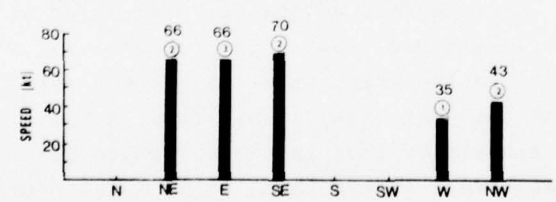

Figure V-83. Average maximum wind gust and direction of winds originating from tropical cyclones passing in the immediate vicinity (within 20 n mi) of Kagoshima.

Figure V-84 shows the position of "threat" tropical cyclone centers when strong winds (≥22 kt) were first and last recorded at Kagoshima. A number of storms gave Kagoshima ≥22 kt winds when they were 300 n mi to the south of the city. Figure V-85 shows tropical cyclone center positions when gale force (≥34 kt) winds were first and last recorded at Kagoshima. It can be ascertained from this figure that winds ≥34 kt generally do not begin until the storm is about 180 n mi away. Notice the preponderance of storms that generate strong or gale force winds originate to the south and west of Kagoshima and that no gale force winds occurred when the storms moved north of 34°N.

The most severe threat to the harbor occurs when a tropical cyclone approaches from the southwest and passes west of Kagoshima within 50 n mi. In this case, winds will flow from the southeast unimpeded the entire length of Kagoshima Bay focusing on the narrow harbor area.

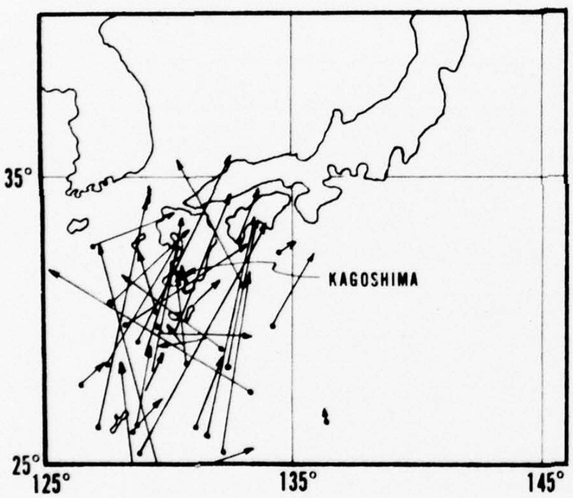

Figure V-84. Positions of 43 tropical cyclone centers when winds ≥22 kt first and last occurred at Kagoshima. (Based on hourly data for the months June-October during the years 1956-1974.)

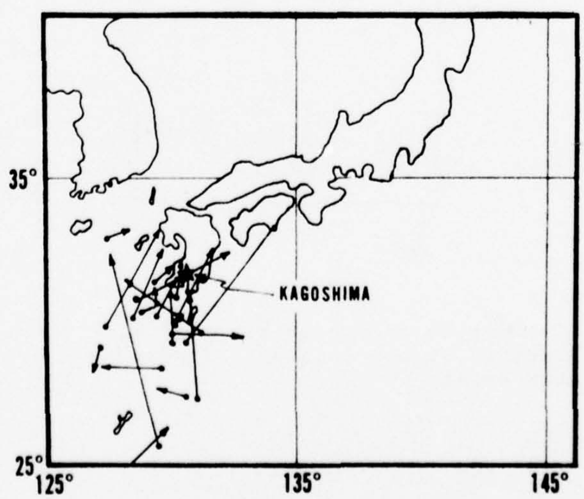

Figure V-85. Positions of 21 tropical cyclone centers when winds ≥34 kt first and last occurred at Kagoshima. (Based on hourly wind data for the months June-October during the years 1956-1974.)

6.4.3 Wave Action

The geographical location of Kagoshima Harbor is such that regardless of whether a tropical cyclone passes east or west of the port, ships anchored in the outer harbor area will experience considerable wave action. Tropical cyclones passing to the east will generate winds from the northeastern quadrant. In this area there is an unbroken fetch of 12 n mi in the northern portion of Kagoshima Bay. In a similar manner, the fetch to the south-southeast of the harbor is approximately 28 n mi over which winds generated by a tropical cyclone passing to the west can flow unimpeded.

Table V-21 shows the wind speed required to generate various wave heights in Kagoshima Harbor based on the direction and length of fetch that the wind blows over.[20]

Table V-21a. Fetch limits (n mi) by direction from Kagoshima Harbor (Honkoh Harbor area).

NE	ENE	E	ESE	SE	SSE
12	3	1.8	1.5	10.2	28.2

Table V-21b. Wind speed (kt) required to obtain indicated wave heights (m) at Kagoshima Harbor (Honkoh Harbor area) by wind direction.

RESULTANT WAVE HEIGHT (meters)	WIND DIRECTION					
	NE	ENE	E	ESE	SE	SSE
0 - 0.5	12.6	20.0	24.0	26.0	13.0	10.0
0.6 - 1.0	22.2	36.0	23.6	46.8	23.0	17.0
1.1 - 1.5	31.6	50.0	60.0	64.0	32.6	24.0
1.6 - 2.0	40.6	64.0	-	-	42.0	30.6
2.1 - 3.0	56.0	-	-	-	58.0	42.0
3.1 - 5.0	-	-	-	-	-	-

[20] From a 10-year study of wind effects on Kagoshima Harbor (1960-1969) prepared by the Japanese Meteorological Agency for the Kagoshima Prefecture government.

During the same period of study that produced Table V-21, additional data shows the frequency distribution of wave height as can be seen in Table V-22.

Table V-22. Frequency of wave height occurrences at Kagoshima Harbor occurring over the 10-year period 1960-1969 (from a Japanese Meteorological Agency study).

WAVE HEIGHT (meters)	NUMBER	PERCENTAGE
0 - 0.5	3015	82.5
0.6 - 1.0	572	15.7
1.1 - 1.5	56	1.5
1.6 - 2.0	7	.2
2.1 - 3.0	3	.1
3.1 - 5.0	1	-
TOTAL	3654	100.0

It should be noted that these tables reflect weather conditions that occurred throughout the entire year for 10 complete years, and included 35 tropical cyclones.

Because of the configuration of the entrance to Kagoshima Bay, swell generated by the storm centers is effectively intercepted. Thus the sea state inside the bay and in the Kagoshima Harbor area is dependent solely on local wind conditions.

6.4.4 Storm Surge

Storm surge may be defined as an abnormal rise of the sea along a shore as the result of the winds of a storm and the pressure drop. The piling up of water on a coast ahead of a tropical storm or typhoon is more apparent in the dangerous semicircle, the region of most intense winds. Kagoshima Harbor is in the dangerous semicircle when a tropical cyclone passes to the west of the area. The surge effect is most evident in the shallow waters of large inland bays that open to the south (Miyazaki, 1974).

Conversations with officials of the Kagoshima Harbor Office and Japanese Maritime Safety Agency indicate that the harbor area is not adversely affected by storm surges.

6.5 THE DECISION TO EVADE OR REMAIN IN PORT

6.5.1 Evasion Rationale

Because of the threat of high winds associated with tropical cyclones and the extremely poor holding quality of the bottom (sand and shale) in the anchorage, Kagoshima Harbor IS NOT CONSIDERED A SAFE TYPHOON HAVEN. Commanding Officers and Masters of vessels must recognize the inherent dangers that exist when exposed to hazardous weather and remaining at an anchorage which has known poor holding qualities.

(At the Nippon Oil Staging Terminal located at Kiire, all pumping from oil tankers is ceased when sustained winds reach 30 kt. When sustained winds reach gale force intensity, ship's masters are advised to leave the terminal and depart the area, preferably to the open sea.)[21]

Figures V-86 through V-90 show the tropical cyclone threat axis for Kagoshima from June-October. The area of the arrows represent approximately a 30% or greater probability of a tropical cyclone coming within 180 n mi of Kagoshima.

For general information on tropical cyclone warnings the reader is referred to paragraphs 6 and 7 of Chapter I.

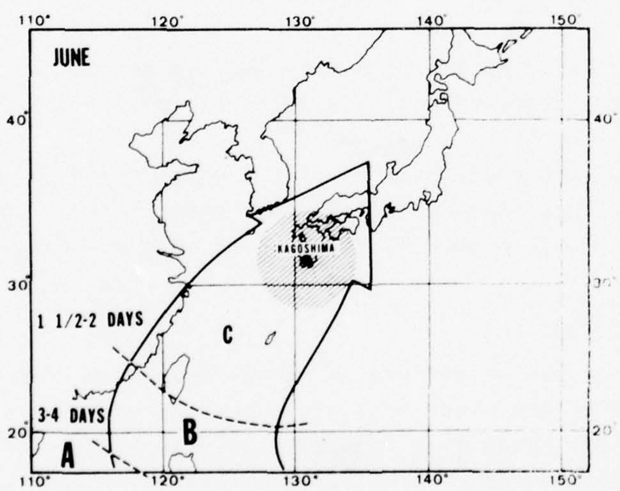

Figure V-86. Tropical cyclone threat axis for Kagoshima for the month of June. Approach times to Kagoshima are based on typical speeds of movement for tropical cyclones affecting Kagoshima.

[21] Based on a conversation with the port captain at Kiire.

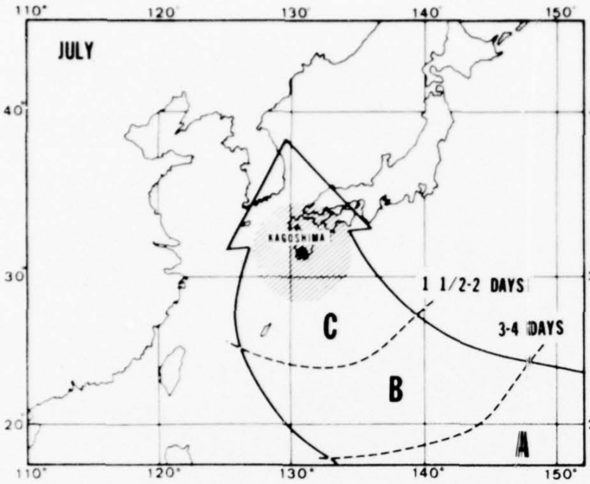

Figure V-87. Tropical cyclone threat axis for Kagoshima for the month of July. Approach times to Kagoshima are based on typical speeds of movement for tropical cyclones affecting Kagoshima.

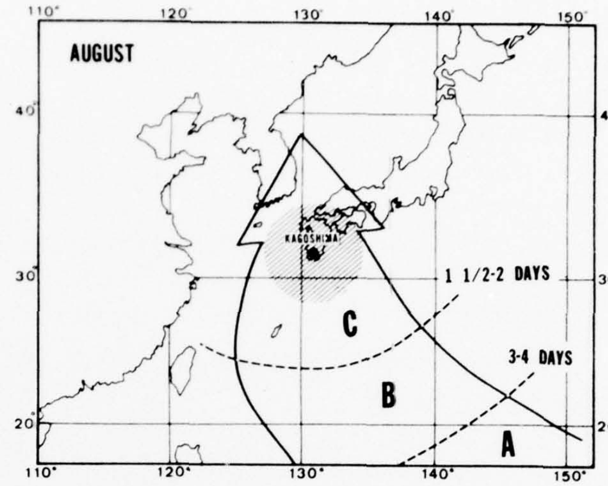

Figure V-88. Tropical cyclone threat axis for Kagoshima for the month of August. Approach times to Kagoshima are based on typical speeds of movement for tropical cyclones affecting Kagoshima.

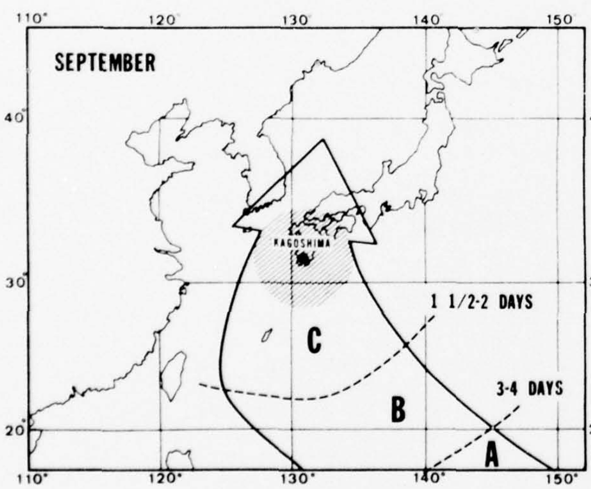

Figure V-89. Tropical cyclone threat axis for Kagoshima for the month of September. Approach times to Kagoshima are based on typical speeds of movement for tropical cyclones affecting Kagoshima.

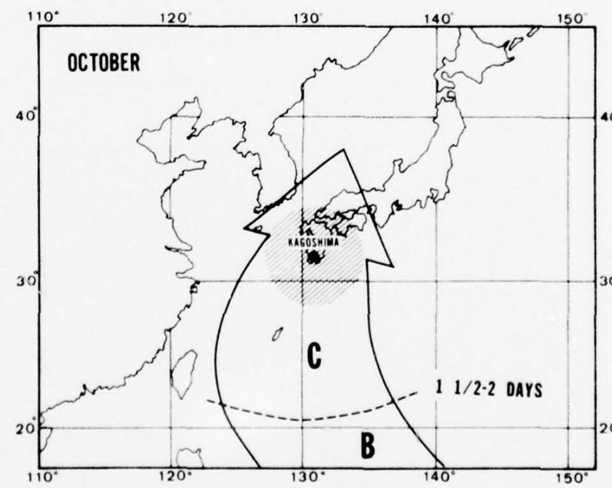

Figure V-90. Tropical cyclone threat axis for Kagoshima for the month of October. Approach times to Kagoshima are based on typical speeds of movement for tropical cyclones affecting Kagoshima.

6.5.2 Evasion

In the southern part of Japan there are two areas that have been evaluated as typhoon havens -- Sasebo in northwestern Kyushu (Rudolph, 1975), and the Kure/Iwakuni area in Hiroshima Bay (Manning, 1975). (Sasebo Harbor is considered an excellent haven but only for vessels smaller than aircraft carriers.)

Since transit time, whether it be to another port or to sea, may be lengthy, evasion must commence early. To facilitate early action, the following time table (in conjunction with Figures V-86 to V-90) has been constructed.

1. An existing tropical cyclone moves into or development takes place in Area A with forecast movement toward Kyushu:

   a. Review material condition of ship. Evasion may be desirable 2-4 days hence. Begin planning course of action to be taken in case of increasing threat.

   b. Reconsider any maintenance that would render the ship incapable of getting underway within 48 hours.

2. Tropical cyclone enters Area B with forecast movement toward Kagoshima:

   a. Execute evasion plans made in previous steps. Evasion should be completed before storm enters Area C. If evasion is to be made to Sasebo, approximately one-half day's steaming time, the commanding officer may elect to delay execution of evasion plans accordingly.

3. Tropical cyclone enters Area C moving toward Kagoshima:

   a. If evasion is not accomplished by this time, evasion from Kagoshima Bay is no longer recommended. If the decision to remain at anchor is made, ensure sufficient power is made available to counter high winds and seas by steaming to the anchor (see paragraphs 5 of Chapter I).

   b. Another course of action would be to get way on the ship, and place the ship's head into the wind and sea (see paragraph 5, Chapter I). Since Kagoshima Bay is large, and with few exceptions deep, the ship can be placed in various locations in the bay to reduce the fetch and thereby reduce the effects of wave action. Movement into the southwestern part of the bay would tend to offset the effects of southeasterly winds. It is not recommended that a ship be placed in the northern regions of Kagoshima Bay, north of Sakurajima, due to the restrictive nature of the area and the shallow water in the middle of this region. (It should be noted that of all the tropical cyclones studied, the longest duration of gale force winds at Kagoshima was 5 hours.)

Evasion routes at sea may be developed by the use of the warnings received from FWC/JTWC and Appendix 1-A (the mean tropical cyclone tracks, track limits, and average speed of movements for the months June-October) in conjunction with Figures V-86 to V-90 (tropical cyclone threat axis and approach times to Kagoshima for the months June-October). In all cases, Optimum Track Ship Routing (OTSR) should be consulted as to the best evasion route. Ships whose ultimate destination is the eastern Pacific may want to consider evading to Yokosuka in south central Honshu (Graff, 1975).

In general, the effects of sea/swell generated by a tropical cyclone may reduce the speed of advance (SOA) thereby increasing the time required to reach the open sea (see paragraph 5, Chapter I). If a ship is caught in the sea/swell pattern ahead of an intense tropical storm or typhoon, the SOA may be reduced to the point that the ship will be unable to maneuver to clear the danger area.

There are two basic evasion tactics. The most common among civilian shipping companies is to place the ship south of the tropical cyclone in the navigable semicircle. The other is to proceed north into the Yellow Sea or Sea of Japan.

In the latter case, the cooler surface water and cool air found at higher latitudes cause a weakening and ultimate dissipation of the tropical cyclone. Therefore, a ship should experience less difficulty in riding out a storm at these latitudes than if it steamed south to seek the navigable semicircle and encountered winds in excess of 80 kt enroute.

7. BUCKNER BAY, OKINAWA

SUMMARY

The conclusion reached by this study is that Buckner Bay is not considered to be a haven during typhoon conditions. The lack of extensive protection from wind due to the relatively low topography of the surrounding land mass and the exposure of ships to wind and seas with any easterly component severely limits Buckner Bay as a storm refuge.

It is recommended that all Navy ships capable take action to evade at sea when typhoon conditions threaten Buckner Bay.

7.1 LOCATION

Okinawa is the principal island in the Ryukyu Islands chain which extends in an arc from off the northeastern coast of Taiwan to the southern end of Kyushu. This chain of islands forms the southeastern boundary of the East China Sea. Okinawa is located 350 n mi south of Kyushu or approximately in the middle of the Ryukyu Island chain.

Oriented roughly northeast to southwest, Okinawa is 58 n mi long and 2.6 to 17 n mi wide. The northern part of the island is rugged, mountainous, and wooded, with few inhabitants and very little cultivated land. The southern part consists of hills and plateaus, is highly cultivated and thickly settled. The topography of Okinawa is depicted in Figure V-91.

A detailed study of the coast and harbors of Okinawa and specific comments on navigation aids and coastal features near Buckner Bay and Naha, is included in H.O. Pub. 156, Sailing Directions (Enroute) for Japan, sector 20.

7.2 BUCKNER BAY HARBOR

The main entrance to Buckner Bay is Tatsu Guchi, located between Ufu Bishi and Tsuken Shima (see Figure V-92). The navigable width of this channel is almost 2 n mi. The second entrance, Kudaka Kuchi, is a little less than 1/2 n mi wide and is located south of Kudaka Shima.

There are numerous anchorages available throughout the bay in a sand, mud and shell bottom. The greater part of Buckner Bay has been wire dragged to a depth of 11 fathoms. Pier area is available at White Beach, the principal facility serving the U.S. Navy.

7.3 TOPOGRAPHY

Figure V-92 depicts the topography of the land masses surrounding Buckner Bay. It is evident that there is virtually no wind protection afforded by topography for winds from east-southeast to south-southwest.

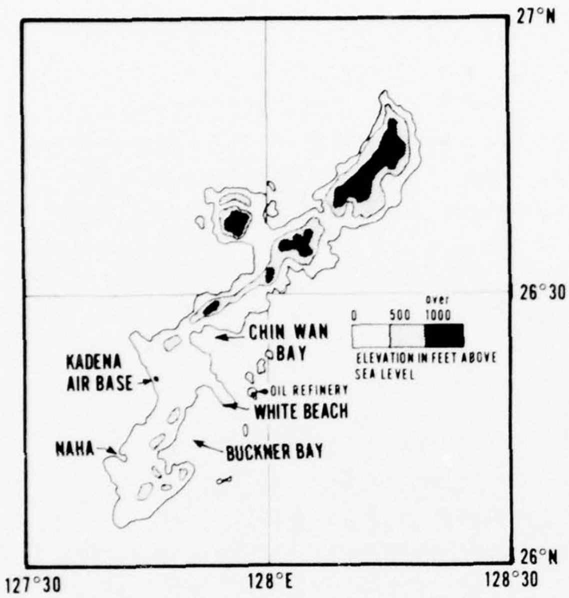

Figure V-91. Topography of Okinawa

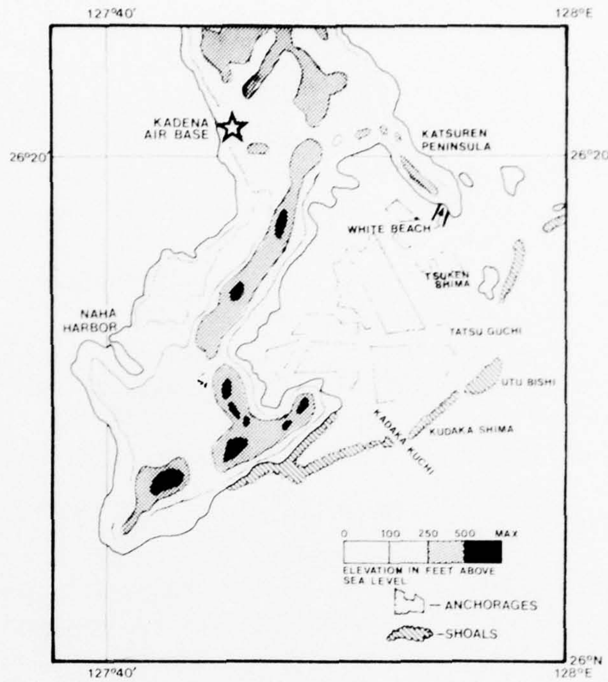

Figure V-92. Southern Okinawa

7.4 HARBOR FACILITIES

There are two piers at White Beach (see Figure V-93). The older of the two, Pier Bravo is an asphalt-surfaced causeway connecting to a steel pier reinforced with concrete. A newer pier, the Navy Pier located east of pier Bravo is used primarily by U. S. Navy vessels while part of pier Bravo is used by the Japanese Maritime Self Defense Force. Information as to pier length and alongside depth can be obtained from the appropriate Port Directory. There are no mooring buoys located within Buckner Bay.

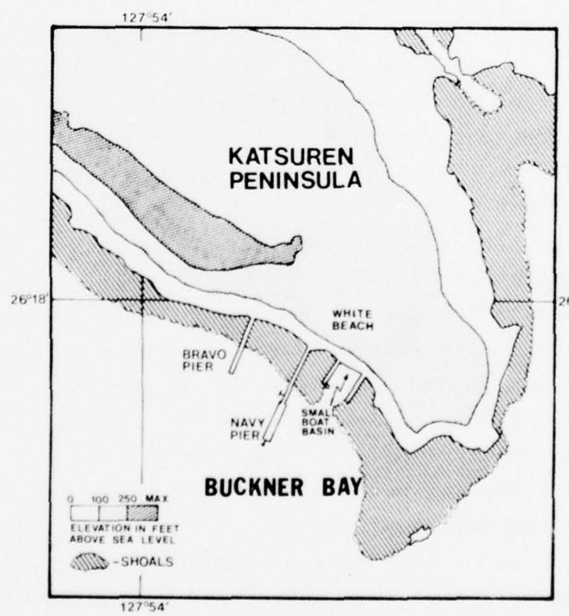

Figure V-93. Pier area of White Beach.

Buckner Bay does not have a tug/pilot available. If tug/pilot assistance is required it must come from Naha Harbor (6 tugs available) or the oil refinery (4 tugs available) located at Kinmu Bay (see Figure V-91). When threatened by a typhoon these tugs will undoubtedly be used first at their primary location before rendering assistance to ships in Buckner Bay. The Port Services Officer at White Beach does have four LCM-6 type pusher boats available which could be of some use during an emergency.

Buckner Bay is not a logistics support port. However, fuel oil, fresh water, and food can be obtained in limited quantities.

7.5 TROPICAL CYCLONES AFFECTING BUCKNER BAY

7.5.1 Tropical Cyclone Climatology For Buckner Bay/Naha Harbors

The climatology of tropical cyclones for Buckner Bay and Naha Harbors are combined here since the two harbors are less than 13 n mi apart. The midpoint of a line between the two harbors was used for the following climatology. For purposes of this study, any tropical cyclone that entered a 180 n mi circle radially outward from this midpoint was considered to be a threat to Buckner Bay/Naha Harbor and designated as a "threat" tropical cyclone.

Tropical cyclones can occur during any month of the year in the western North Pacific area. However, the majority of those that pose a threat to Buckner Bay/Naha occur during the months of May-December. Climatological records indicate that during this period Okinawa is either within or closely adjacent to the mean tropical cyclone track (see Appendix 1-A) and therefore has the dubious distinction of being located in the middle of "Typhoon Alley."

The peak "threat" period for Buckner Bay/Naha extends from July through September. This is indicated in Figure V-94 which depicts the monthly summary by 5-day periods of tropical cyclone occurrences and is based on data from May-December, 1947-1973. During this 27-year period, 115 tropical cyclones "threatened" Buckner Bay/Naha, for an average of approximately four tropical cyclones per year. August is the peak "threat" period (27%) followed by July and September. Only 5% of the "threat" tropical cyclones occurred during May and December. Figure V-94 also indicates that almost half of the "threat" tropical cyclones are "recurvers" (had a northeasterly component of motion at their closest point of approach to Buckner Bay/Naha after an initial northwestward component of motion).

Figure V-95 displays the "threat" tropical cyclones according to the compass octant from which they approached Buckner Bay/Naha. The circled numbers indicate the total that entered from an individual octant. The adjacent numbers express this as a percentage. It is evident that 60% of the "threat" tropical cyclones entered the threat area from a sector extending from SW to SE.

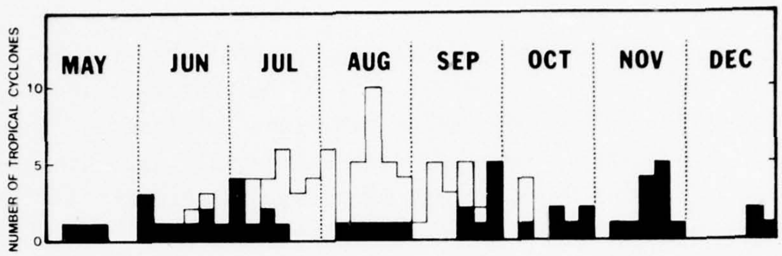

Figure V-94. Frequency distribution of the number of tropical cyclones that passed within 180 n mi of Buckner Bay/Naha. Subtotals are based on 5-day periods, for tropical cyclones that occurred during 1947-1973. The shaded area indicates the number of recurving tropical cyclones per 5-day period (northeasterly direction of motion at their closest point of approach to Buckner Bay/Naha after an initial northwesterly direction of motion).

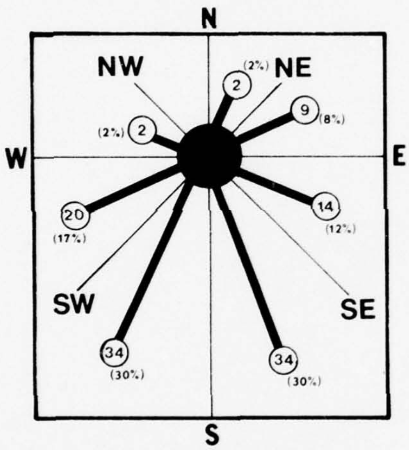

Figure V-95. Directions from which tropical cyclones entered threat area (a 180 n mi radius circle centered at the middle of a line between Buckner Bay and Naha during the period May-December, 1947-1973. Numbers circled indicate the number of tropical cyclones that entered from each octant. This is expressed as a percentage adjacent to the circled number.

Table V-23 indicates that, out of the 115 "threat" tropical cyclones during May-December, 1947-1973, 57 passed the midpoint of a line connecting Buckner Bay/Naha to the east and 58 passed to the west. Therefore, the chance of having a "threat" tropical cyclone pass to the west or east of Buckner Bay/Naha during the typhoon season is equal. However, it is interesting to note that during June, July, and September, the majority of "threat" tropical cyclones pass to the west of Buckner Bay/Naha, while during May, August, October, November, and December the likelihood of having a tropical cyclone pass to the east of Buckner Bay/Naha is greater.

Table V-23. "Threat tropical cyclone passage relative to the midpoint of a line between Buckner Bay and Naha.

	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Passed east of midpoint	3	2	7	18	9	6	9	3	57
Passed west of midpoint	0	9	18	13	12	3	3	0	58

BUCKNER BAY, OKINAWA

Figures V-96 to V-103 represent analyses of the probability of any tropical cyclone approaching within 180 n mi of Buckner Bay/Naha for May through December, respectively. The solid lines represent the "percent threat" for any storm location. The dashed lines represent approximate approach times to Buckner Bay/Naha, computed from average tropical cyclone speeds of movement for tropical cyclones affecting Buckner Bay/Naha during May-December (speeds of movement were derived from climatological data (U.S. NWSED, Asheville, 1973). For example, a tropical cyclone located at 20N/119E in May has a 40% probability of coming within 180 n mi of Buckner Bay/Naha and it can hit Buckner Bay/Naha in about 1½-2 days (see Figure V-96).

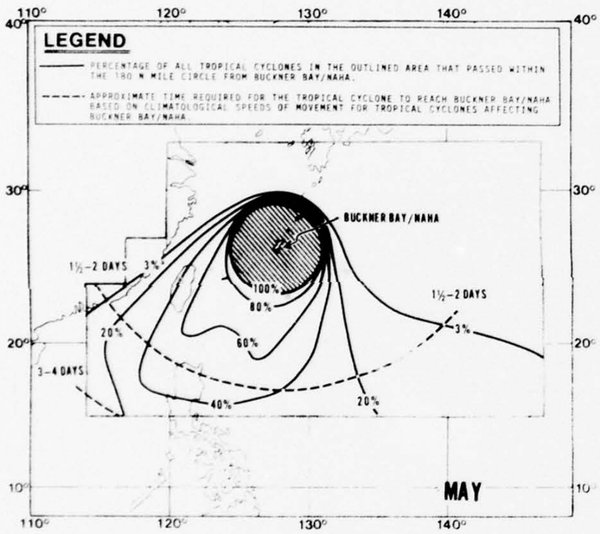

Figure V-96

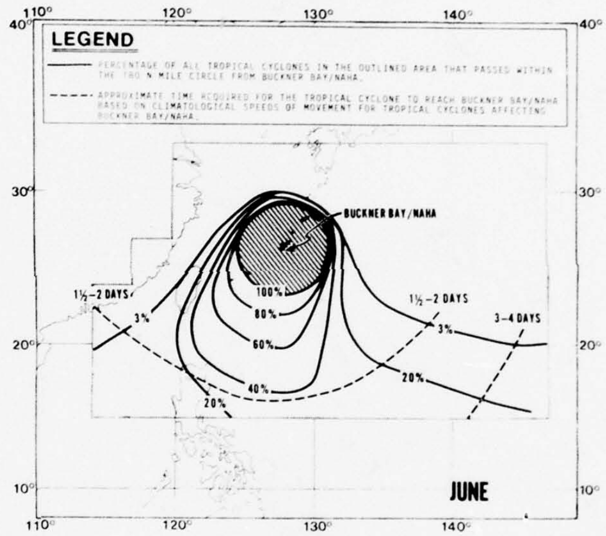

Figure V-97

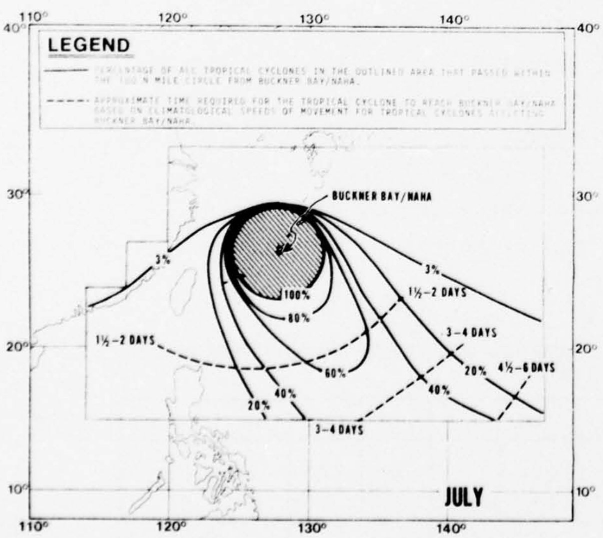

Figure V-98

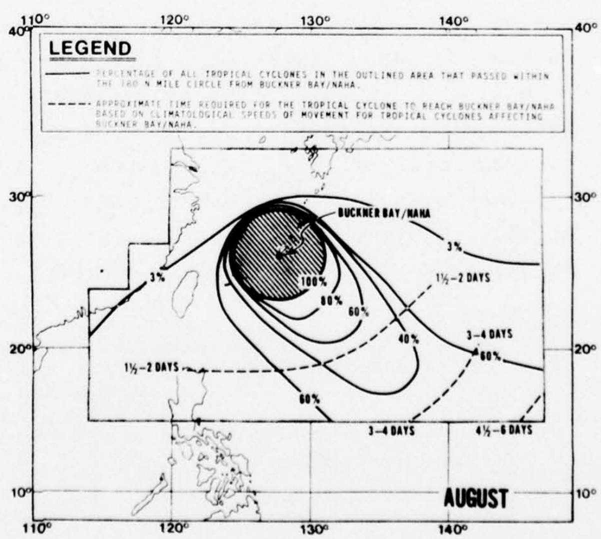

Figure V-99

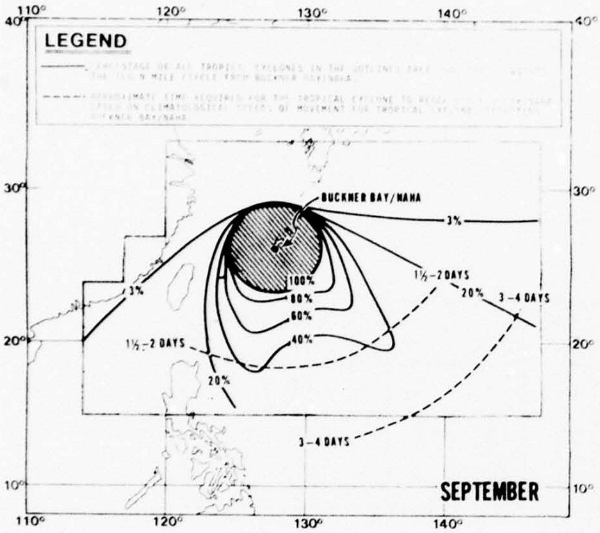

Figure V-100

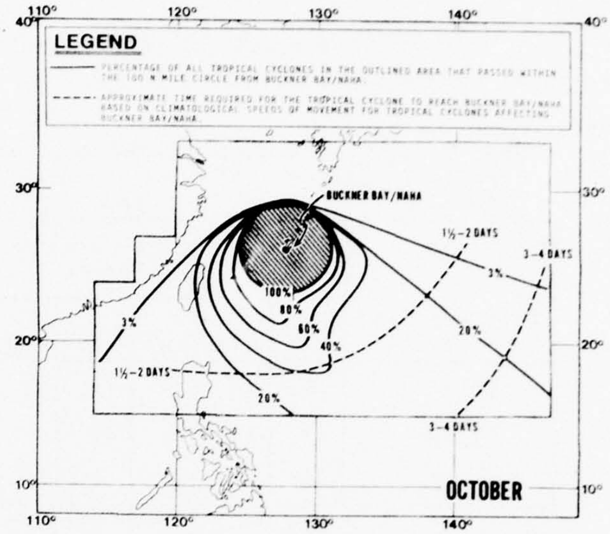

Figure V-101

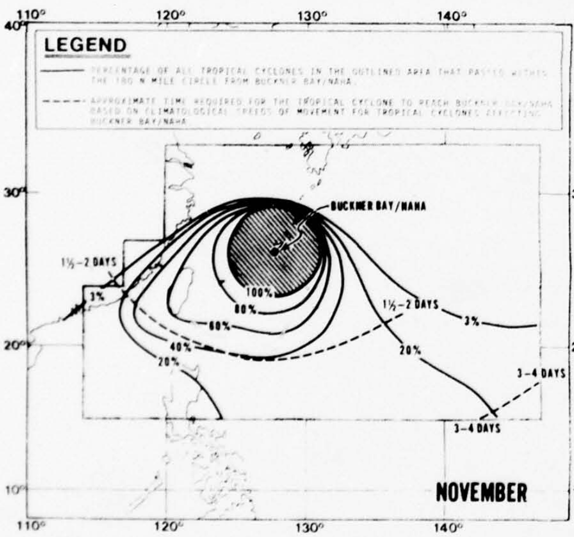

Figure V-102

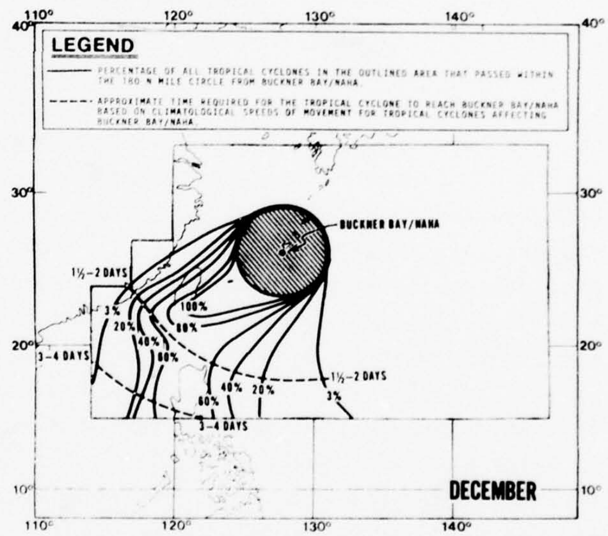

Figure V-103

Note the significant shift in direction from which "threat" tropical cyclones approach Buckner Bay/Naha (Figures V-96 to V-103). In May, June, November, and December the "threat" is generally from the southwest, whereas in July-October the "threat" is generally from the south to southeast.

The average speeds of movement of tropical cyclones affecting Buckner Bay/Naha are presented in Table V-24.

Table V-24. Listing of May-December average climatological speeds of tropical cyclones affecting Buckner Bay/Naha by 5-degree latitude bands.

Latitude Band (°N)	Average Forward Speed of Movement (kt)								Average of the 8 Months (kt)
	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
20-35	15	14	11	11	13	13	18	13	13.5
15-20	11	13	10	10	11	12	13	10	11.2
10-15	10	10	9	9	10	12	12	9	10.1

7.5.2 Wind And Topographical Effects

Based on topographical considerations, strong winds can be expected from a sector extending from the east to the south since little topographic protection is available from these directions (see Figures V-92 and V-93).

To determine the extent to which "threat" tropical cyclones produced strong winds (≥22 kt) or gale force winds (≥34 kt) in Buckner Bay, the wind observations from Kadena Air Base (26°21'N, 127°45'E) were analyzed for the period May-December, 1947-1972. Figure V-92 shows the location of Kadena Air Base and surrounding topography. It must be noted that winds generally from the east and south will be 10-20% stronger in Buckner Bay than at Kadena Air Base due to the local topography. In addition, winds generally from the west will be 10-20% less at Buckner Bay than the winds recorded at Kadena Air Base. This "bias" must be kept in mind in the following paragraphs.

Table V-25 groups the 110 tropical cyclones that "threatened" Buckner Bay during the 26-year period, May-December, 1947-1972 according to the extent to which they affected Buckner Bay. Approximately two thirds of the tropical cyclones that came within 180 n mi of Okinawa produced ≥22 kt winds at Kadena and one third produced gale force winds or greater (≥34 kt).

Table V-25. Extent to which "threat" tropical cyclones affected Buckner Bay during May-December, 1947-1972.

Number of tropical cyclones that "threatened" Buckner Bay	110	%
Number of "threat" tropical cyclones resulting in strong (≥22 kt) winds in Buckner Bay	75	68%
Number of "threat" tropical cyclones resulting in gale force (≥34 kt) winds in Buckner Bay	38	34%

From an analysis of the "threat" tropical cyclone tracks that affected Buckner Bay the following is apparent: (1) Gale force winds resulting from a "threat" tropical cyclone occurred in each month during June-December and (2) August had the greatest number of "threat" tropical cyclones which produced gale force winds in Buckner Bay.

Figure V-104 shows the positions of "threat" tropical cyclone centers when strong winds (≥22 kt) first began and ended at Buckner Bay. It is apparent that "threat" tropical cyclones as far south as 21-22N and as far north as 30N can produce strong winds at Buckner Bay.

Figure V-105 shows tropical cyclone center positions when gale force (≥34 kt) winds were first and last experienced at Buckner Bay. It can be seen that gale force winds (≥34 kt) *generally do not begin until the "threat" tropical* cyclone is at a latitude of 24N to 25N. Also, the almost symmetric distribution of arrows indicates that Okinawa's topography has little effect in reducing the intensity of the winds produced by the "threat" tropical cyclone.

For a more detailed discussion on the effects of tropical cyclones on Okinawa, see Rudolph, et al., 1975.

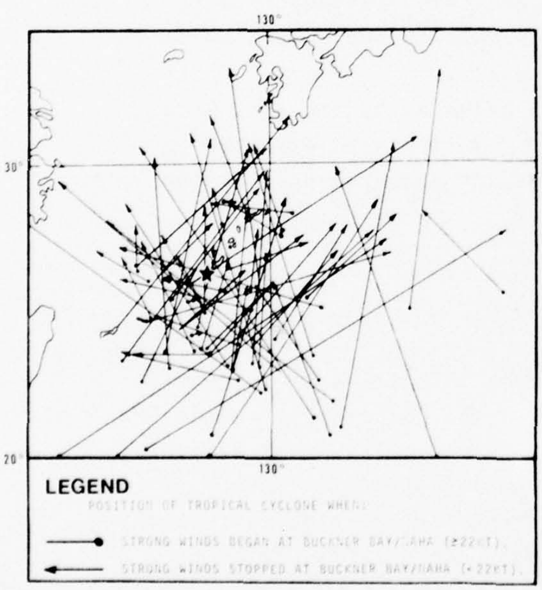

Figure V-104. Positions of tropical cyclone centers when ≥22 kt winds first and last occurred at Buckner Bay/Naha. (Based on May-December data from the years 1947-1972.)

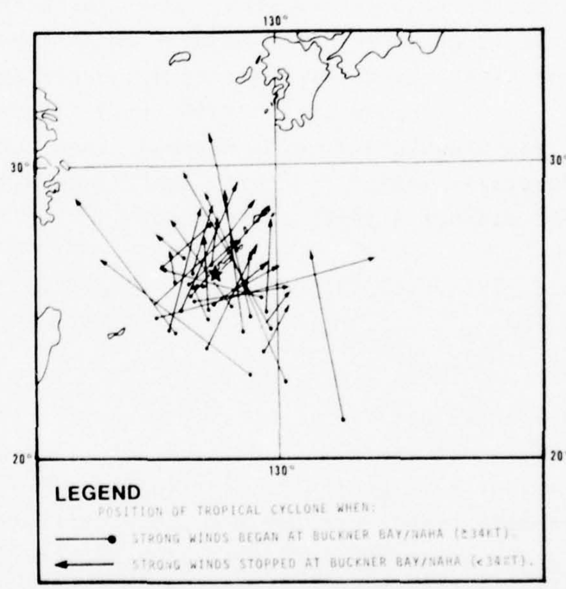

Figure V-105. Positions of tropical cyclone centers when ≥34 kt winds first and last occurred at Buckner Bay/Naha. (Based on May-December data from the years 1947-1972.)

7.5.3 Wave Action

The wave heights that can be expected with typhoon strength winds (≥64 kt) in Buckner Bay are presented as Table V-26.

Table V-26. Wave heights that can be expected with typhoon strength winds (≥64 kt) in Buckner Bay (based on research conducted by the U.S. Naval Oceanography Office.

	White Beach	Middle of Bay
Winds generally from the north (tropical cyclone passage east of Buckner Bay)	4 ft	6 ft
Winds generally from the south (tropical cyclone passage west of Buckner Bay)	20 ft	16 ft

Heights of up to 20 ft can be expected from a typhoon passing within 20 n mi to the west of Buckner Bay. The resulting southerly winds generate waves which are virtually unopposed before reaching White Beach, although the coral reefs and islands surrounding Buckner Bay offer some resistance.

7.5.4 Storm Surge And Tides

When a tropical cyclone crosses a coastline, a rise in water level may occur. This is caused by wind stress on the water surface and effects of atmospheric pressure reduction. For storms approaching Okinawa from the south, this surge effect will be maximum in bays which open to the south and east if the harbor is located in the dangerous semicircle.

According to statistical information gathered by the U.S. Naval Oceanographic Office, a maximum storm surge of 7.8 ft can be expected. Generally some flooding is associated with typhoons approaching from the east. The maximum tide at Buckner Bay is 5.7 ft.

7.6 THE DECISION TO EVADE OR REMAIN IN PORT

7.6.1 General

The responsibility for overall coordination of action to be taken by Naval activities on Okinawa has been assigned to the Commanding General, Marine Corps Base, Camp Butler. The established procedures in the event hazardous weather is expected is contained in SOPA (OKINAWA) INSTRUCTION 5000.1 (series). Storm/typhoon doctrine and coordination procedures for naval forces operating in the COMNAVFORJAPAN area of responsibility has been established by COMNAVFORJAPAN INST 3140.1J (series).

For general information about tropical cyclone warnings the reader is referred to paragraphs 6 and 7 of Chapter I.

7.6.2 Remaining In Port

Remaining in Buckner Bay when threatened by a typhoon is not the recommended course of action for the following reasons:

(1) There is almost no protection available in the bay for winds with an easterly or southerly component.

(2) Sea states up to 20 ft are possible in Buckner Bay.

(3) A storm surge is experienced when a typhoon approaches. This surge may be in excess of 7 ft.

(4) Ships moored at the White Beach piers may not have tug services available to get underway if needed.

6.6.3 Evasion

Evasion from Buckner Bay when threatened by a typhoon is the recommended course of action for all ships to follow. Figures V-106 to V-113 portray the tropical threat axes for Buckner Bay/Naha for the months of May-December, respectively. Approach times are based on average climatological speeds of movement for tropical cyclones affecting Buckner Bay/Naha.

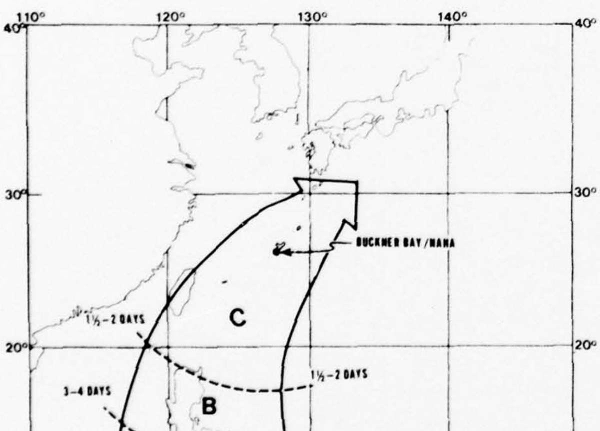

Figure V-106. MAY

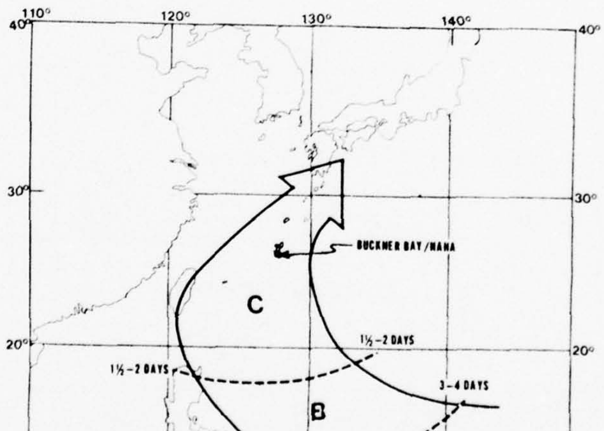

Figure V-107. JUNE

BUCKNER BAY, OKINAWA

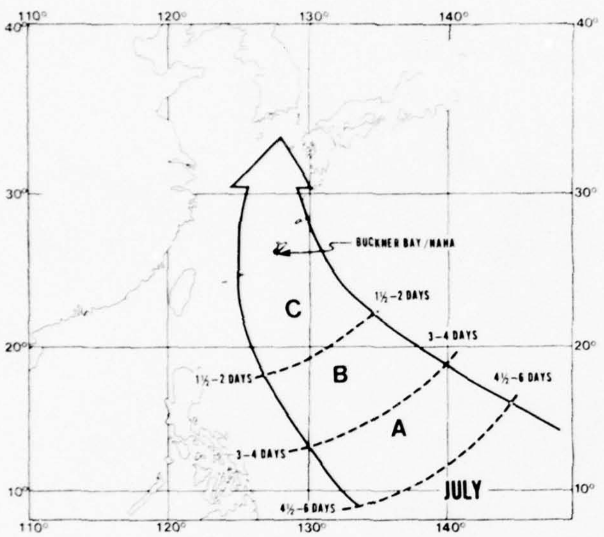

Figure V-108. JULY

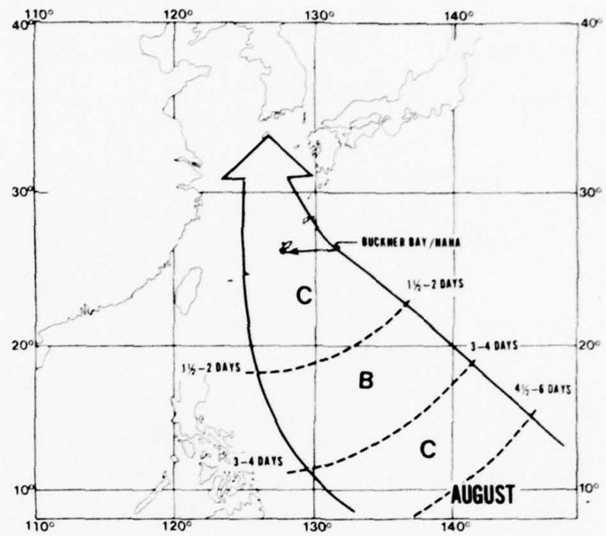

Figure V-109. AUGUST

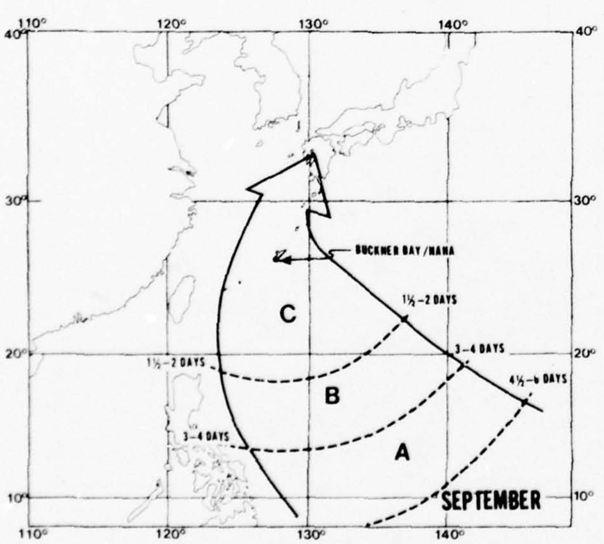

Figure V-110. SEPTEMBER

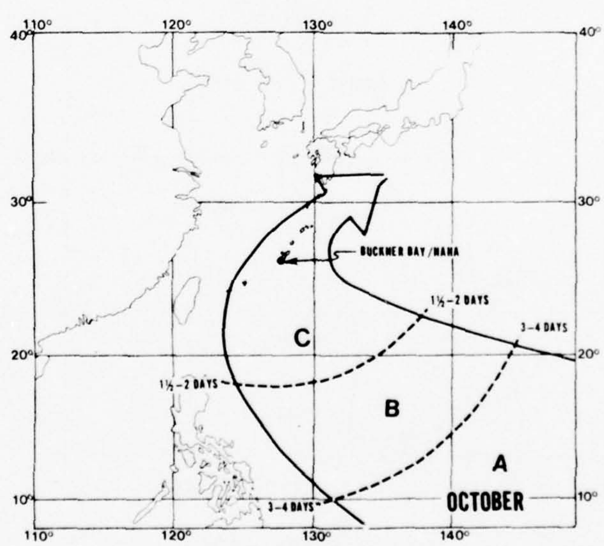

Figure V-111. OCTOBER

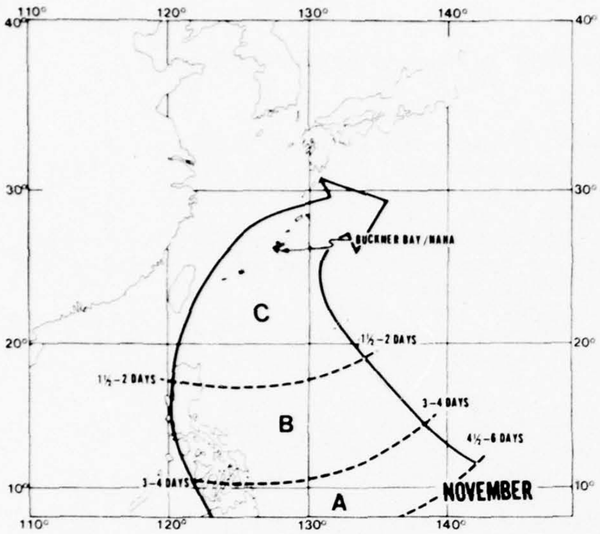

Figure V-112. NOVEMBER

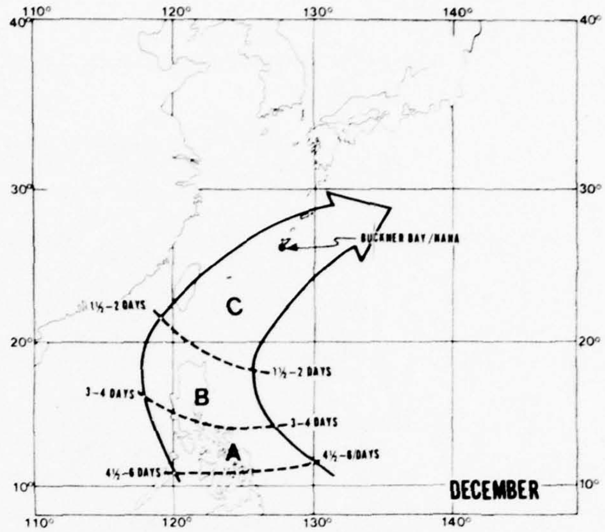

Figure V-113. DECEMBER

To correctly assess the threat posed by an approaching tropical cyclone, the following timetable incorporating Figures V-106 to V-113 has been constructed for this purpose.

I. An existing tropical cyclone moves into, or development takes place in, Area A with forecast movement toward Okinawa.

   a. Review material condition of ship. A sortie may be desirable 2-4 days hence.

   b. Reconsider any maintenance that would render the ship incapable of getting underway within 48 hours.

   c. Plot FWC/JTWC, Guam warnings and construct the danger area. Reconstruct the danger area for each new warning.

II. Tropical cyclone enters Area B moving toward Buckner Bay/Naha.

   a. All ships begin planning course of action to be taken if sortie should be ordered.

   b. Reconsider any maintenance that would render the ship incapable of getting underway within 24 hours.

   c. Anticipate Storm/Typhoon Condition III.

III. Tropical cyclone enters Area C moving toward Buckner Bay/Naha.

   a. Execute sortie plan made in previous step.

   b. Anticipate Storm/Typhoon Conditions II and I.

Whatever evasion decision is made, the following general comments should be considered.

1. When departing Buckner Bay/Naha Harbor, ample time should be given to combat the heavy sea condition likely to be encountered at the entrance to Buckner Bay/Naha Harbor.

2. Crossing ahead of a typhoon should be accomplished well in advance. Heavy swells may be encountered ahead of an advancing typhoon long before the occurrence of strong winds. Such swells may decrease a ship's maneuverability and speed of advance, preventing avoidance of the typhoon (see Chapter I, paragraph 5).

3. At certain times of the year, particularly in the peak typhoon season, the possibility exists that two or more tropical cyclones will be present at one time. This will greatly complicate any evasion planning and execution.

4. A looping tropical cyclone can cause a false sense of security as evading ships attempt to return. A looping storm after initial passage can return and cause as high or higher winds/seas upon its return.

7.6.4 Evasion Techniques

The final decision involving evasion of a tropical storm rests with the commanding officer of the vessel involved. One of the more successful Pacific Ocean evasion techniques involves running downwind and downsea relative to the typhoon in order to reach a latitude south of the storm and be located in the navigable semicircle. The success of this method depends upon almost continuous reconnaissance coverage and the relatively slow movement and gradual expansion of the initially small area affected by severe winds which is characteristic of typhoons at low latitudes.

For a ship in or near Buckner Bay/Naha the following evasion routes for the more common threat situations (depicted in Figure V-114) are suggested.

1. Tropical cyclone is forecast to pass east of Buckner Bay/Naha (Figure V-114 (a)).

   Evasion should be to the southwest. This allows the ship to gain a latitude south of the storm center in the safe semicircle.

2. Tropical cyclone is forecast to pass west of Buckner Bay/Naha (Figure V-114 (b)).

   Evasion should be to the east-southeast. This provides ample maneuvering room and allows course modification to the east or north as the storm movement/intensity varies. A WORD OF CAUTION -- the ship is operating in the dangerous semicircle and wind and sea will be between bow and beam and may adversely affect the ship speed (see Chapter I, paragraph 5). Sufficient separation from the storm center must be maintained to stay outside the 30-kt wind radius.

3. Tropical cyclone is forecast to recurve and pass south of Buckner Bay/Naha (Figure V-114 (c)).

   Evasion should be to the north or northwest. This will place the ship in the safe semicircle and also make available a second option -- to proceed to Sasebo Harbor, a typhoon haven for all but the largest of ships (Rudolph, 1975).

4. Tropical cyclone is forecast to recurve and pass north of Buckner Bay/Naha (Figure V-114 (d)).

   Evasion should be to the east-southeast. This will provide ample maneuvering room and place the ship south of the tropical cyclone. A WORD OF CAUTION -- the ship will be operating in the dangerous semicircle and ships speed may be reduced significantly (see Chapter I, paragraph 5).

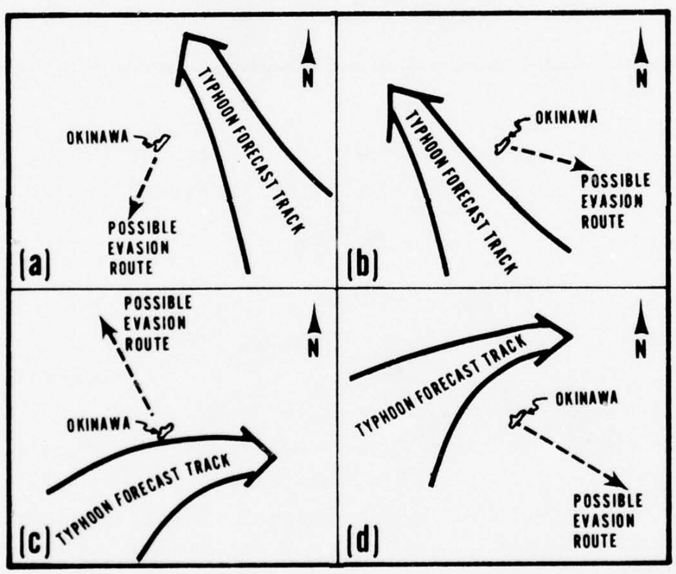

Figure V-114. Common typhoon threat situations experienced at Buckner Bay/Naha and possible evasion routes.

Since the general movement of tropical cyclones varies from month to month, the appropriate information presented in Figures V-96 to V-103 (percent "threat" lines), Figures V-106 to V-113 ("threat" axis diagrams) and Appendix 1-A (the mean monthly tropical cyclone tracks, track limits and average speeds of movement), in conjunction with the warnings issued by FWC/JTWC Guam, should all be used in developing a viable evasion route.

8. NAHA, OKINAWA

SUMMARY

The conclusion reached in this study is that Naha Harbor is a poor haven during typhoon conditions. The key factors in reaching this conclusion were:

1. Lack of sheltered berths.

2. The threat of other vessels adrift in the confined harbor.

3. High sea states within the harbor area for winds of 25 kt and greater.

4. Poor anchor holding action of the harbor bottom.

It is recommended that all U.S. Navy ships capable take action to evade at sea when typhoon conditions threaten Naha, Okinawa.

8.1 LOCATION

Naha, the principal port of Okinawa, is located on the southwestern coast of the island at 26°13'N, 127°41'E. Refer to paragraph 7.1 of Chapter V.

8.2 NAHA HARBOR

Naha Harbor consists of an outer harbor, with outer and inner anchorages, and two inner harbors (Figure V-115). The main inner harbor (Naha Ko) is used by ocean-going vessels with a draft up to 31.5 ft, while the new inner harbor is used by coastal vessels under 3,000 tons.

Figure V-116 depicts the main inner harbor which is divided into a commercial area (northern part) and an Army area (southern part) which has eight piers. The commercial wharfs are letter designated A through L. Piers A-D and J-L are "small craft" piers while pier E is not used.

The inner and outer anchorages are not individually charted and several sunken wrecks within the anchorages are hazards to those vessels lacking local knowledge. The anchorages are exposed to wind and sea and the bottom is considered very poor holding ground.

The tidal range in the harbor is about 6 ft while mean currents do not exceed 2.5 kt.

8.3 TOPOGRAPHY

Figure V-92 indicates that Naha Harbor is unprotected to the northwest but receives some protection from hills less than 250 ft to the north and south. More protection is available to the east.

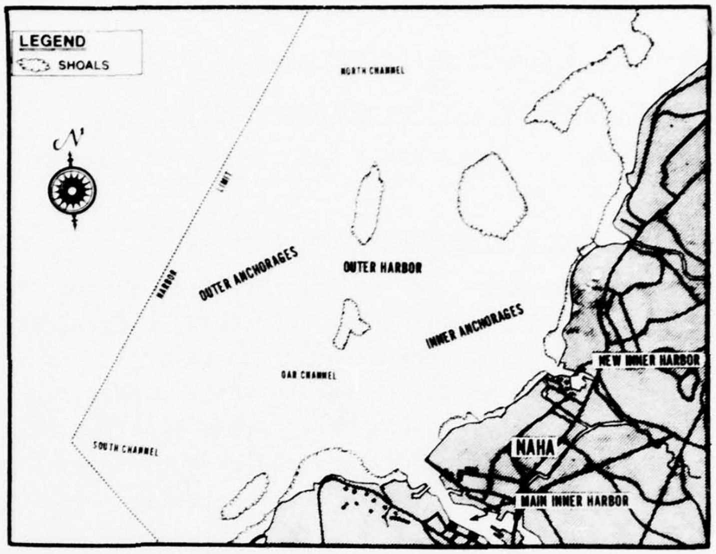

Figure V-115.
Naha Harbor.

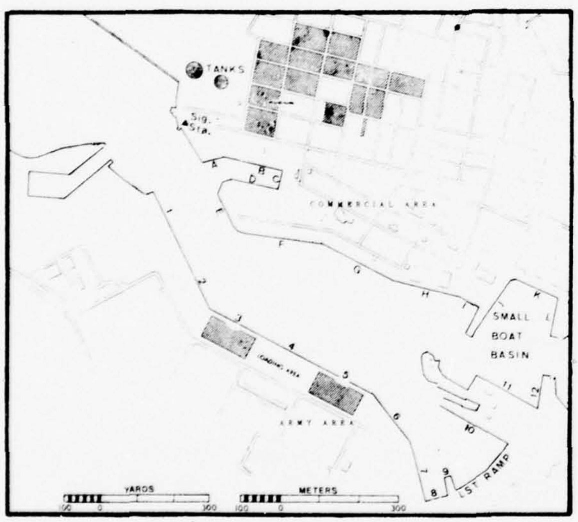

Figure V-116. Naha main inner harbor (Naha Ko).

8.4 HARBOR FACILITIES

The Director for Terminal Operations, 2nd Logistical Command, U.S. Army, is responsible for the operation of facilities and services in the military terminal complex of the port, while the Japanese Maritime Safety Agency (JMSA) controls the commercial complex. For a detailed description of harbor facilities available in Naha, refer to the CINCPACFLT or Far East Port Directory.

8.5 TROPICAL CYCLONES AFFECTING NAHA

8.5.1 Tropical Cyclone Climatology For Naha

Refer to paragraph 7.5.1, Chapter V for the tropical cyclone climatology of Naha.

8.5.2 Wind And Topographical Effects

Maximum winds can be expected from the northwest at Naha since the harbor opens to the ocean in this direction. Thus, tropical cyclones to the north of Okinawa are severe problems to Naha.

To determine the extent to which threat tropical cyclones produced strong winds ($\geq$22 kt) or gale force winds ($\geq$34 kt) in Naha Harbor, the wind observations from Kadena Air Base (26°21'N, 127°45'E) at an elevation of 152 ft were analyzed (refer to paragraph 7.5.2, Chapter V). Since both Naha Harbor and Kadena Air Base are located on Okinawa's western coastline and the surrounding topography is similar, winds recorded at Kadena Air Base are representative of wind conditions experienced in Naha Harbor.

For a more detailed discussion on the effects of tropical cyclones on Okinawa, see Rudolph, et al., 1975.

8.5.3 Wave Action

Wave action in Naha Harbor area is severe enough to halt all traffic with the onset of 25 kt or greater winds. Although ships have been moved in winds up to 50 kt during emergency conditions, wave action in the harbor can be destructive enough to necessitate clearing the port of all vessels when winds of 50 kt or greater are expected within 24 hours.

The wave heights that can be expected with typhoon strength winds ($\geq$64 kt) in Naha Harbor are presented as Table V-27.

Table V-27. Wave heights that can be expected with typhoon strength winds ($\geq$64 kt) in Naha's main inner and outer harbor. (Based on information from U.S. Army Coastal Engineering Research Center, 1973.)

	Main Inner Harbor	Main Outer Harbor
Winds generally from the north (tropical cyclone passage east of Naha)	8 ft	15 ft
Winds generally from the south (tropical cyclone passage west of Naha)	4 ft	12 ft

8.5.4 Storm Surge And Tides

During periods of moderate to strong northwesterly winds, a surge effect of 2-3 ft is evident in the main inner harbor. This is caused by wind stress on the water surface and the effects of atmospheric pressure reduction. When this surge effect coincides with high tide, an abnormal rise in water level occurs.

8.6 THE DECISION TO EVADE OR REMAIN IN PORT

8.6.1 General

For general information about tropical cyclone warnings the reader is referred to paragraphs 6 and 7 of Chapter I. See also paragraph 7.6.1 of Chapter V.

8.6.2 Remaining In Port

Naha is a confined, generally unsheltered harbor. The anchorages are exposed to wind and sea and the bottom is considered very poor holding ground. Several merchant ships may be present at any given time in Naha Harbor, and some of these vessels may have inadequate or poorly maintained mooring gear. As a result, it is possible for them to break loose during typhoon conditions and cause damage to other ships. As a consequence, it is recommended that U.S. Navy ships sortie when typhoon conditions threaten. If a ship is unable to get underway and evade at sea, every effort must be made to obtain a berth within Naha Ko, the main inner harbor. If such a berth cannot be obtained well in advance of the onset of heavy weather, evasion at sea is strongly recommended.

8.6.3 Evasion

Evasion from Naha Harbor when threatened by a typhoon is the recommended course of action for all ships to follow. See paragraph 7.6.3 of Chapter V for general evasion comments.

8.6.4 Evasion Techniques

Due to the proximity of Buckner Bay and Naha Harbor, the evasion techniques presented in paragraph 7.6.4 of Chapter V are applicable.

REFERENCES

INSTRUCTIONS/NOTICES

Commander in Chief, U.S. Pacific Fleet
CINCPACFLT OPORD 201-(YR) Annex H

Commander, U.S. Seventh Fleet
COMSEVENTHFLT OPORD 201-(YR) Annex H

Commander, U.S. Naval Forces Japan
COMNAVFORJAPANINST 3140.1 (series)

Commander, U.S. Fleet Activities, Yokosuka
COMFLEACTINST 3140.1 (series)
COMFLEACTINST 5000.1 (SOPA ADMIN)

Commander, U.S. Fleet Activities, Okinawa
COMFLEACTINST 5000.1 (SOPA OKINAWA)

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COMFLEACTINST 5000.1 (SOPA ADMIN)

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Rudolph, D. K., F. J. Blake, S. Brand and J. Blelloch, 1975: An Evaluation of the Harbors of Buckner Bay and Naha, Okinawa as Typhoon Havens. NAVENVPREDRSCHFAC Technical Paper No. 21-75.

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SECTION VI - CONTENTS

VI PHILIPPINE ISLANDS

1. GENERAL

The Philippines constitute the largest island group, in terms of numbers, of the Malay Archipelago. They comprise approximately 7100 islands and islets, of which Luzon is the largest, covering an area of approximately 115,600 square miles.

2. EFFECT OF PHILIPPINE ISLANDS ON TROPICAL CYCLONES

The degree of land influence on a tropical cyclone is a function of the area and topography over which the storm is passing. Figure VI-1 depicts the topography of the Philippine Islands. It can be seen that the terrain of the Philippine Islands varies a great deal, ranging from extensive mountainous regions on Luzon and Mindanao to a sea-land mix in the central Philippine Islands.

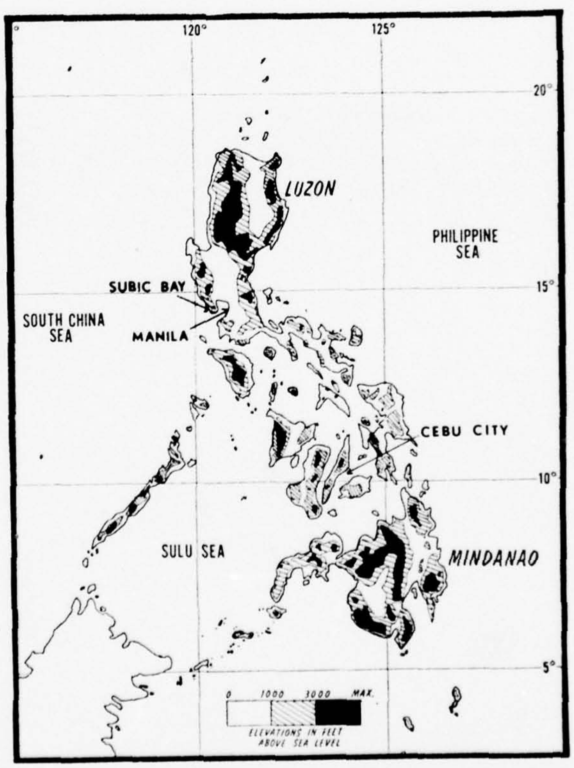


Figure VI-1. The Philippines.

PHILIPPINE ISLANDS

Brand and Blelloch (1972) showed that the intensity, speed, and circulation size of typhoons can be greatly influenced by the Philippine Islands. Two of these parameter changes are depicted in Figures VI-2a and VI-2b. The typhoons used in this study were divided into two categories: intense typhoons, or those having an initial average intensity $\geq$90 kt in the 24-hr period prior to crossing the Philippines, and weak typhoons, or those having an average initial intensity <90 kt in the 24-hr period prior to crossing the Philippines. The intensity of intense typhoons decreased 45-50 percent in maximum sustained wind, while the weak typhoons decreased in intensity only 10-15 percent. The speed of intense typhoons shows little decrease, while weaker typhoons, which move faster, show a marked decrease in speed (see Figure VI-2b). The circulation size of all typhoons considered decreased by an average of 17% in areal extent when crossing the Philippines.

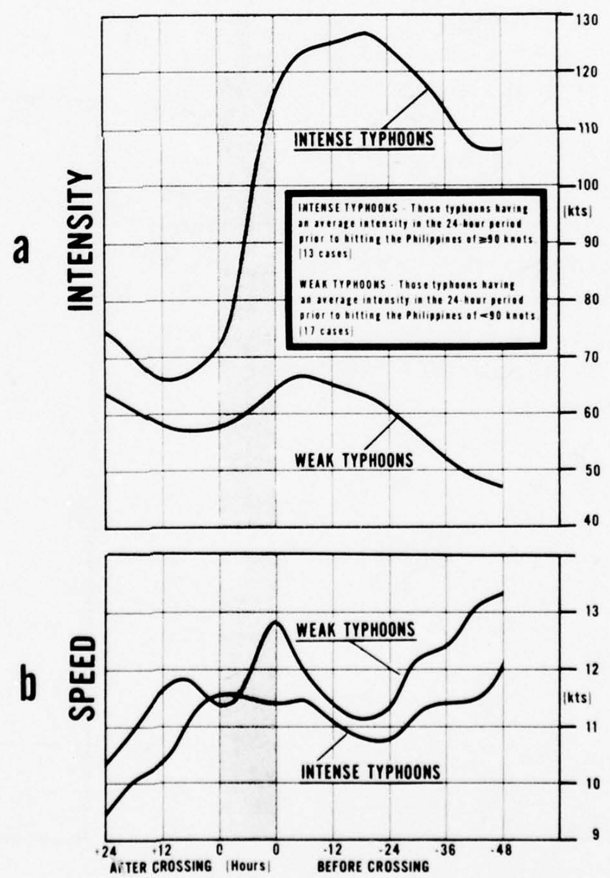


Figure VI-2. Average intensity (a) and speed (b) profiles for intense and weak typhoons crossing the Philippines (Brand and Blelloch, 1972).

3. SUBIC BAY

SUMMARY

Previous texts classifying Subic Bay as a typhoon haven have done so with certain reservations or qualifications. It is true that many ships have successfully weathered the numerous typhoons which have affected Subic Bay. However, it is also a fact that Subic Bay has never really been tested by the passage of a truly severe tropical cyclone. Those storms whose eyes have crossed directly over Subic Bay have been relatively weak storms; in the case of severe tropical cyclones the eyes have only come close, with the strongest winds missing Subic Bay by 50-100 n mi, and the remaining winds being further reduced by the topography of the surrounding terrain. The highest sustained wind recorded during the period 1955-1973 was 56 kt.

In any event, it is felt that the potentially most dangerous situation is not presented by a cyclone passing directly over Subic, but rather by a close south-southwestward passage between 15-50 n mi. Consider a case where a cyclone has crossed the Philippines through the San Bernardino Strait, losing little of its intensity, and then moves northward (perhaps starting to recurve), so that the eastern and southern portions of the wall cloud and feeder band activity have unobstructed access to the bay.

After considering the above facts and after many discussions with experienced personnel at Subic Bay, it is the conclusion of this study that, although Subic Bay does provide some degree of shelter from typhoon passage, it should not be considered an "unqualified" typhoon haven. The sheltering effect provided by the surrounding terrain qualifies Subic Bay as a much safer port in heavy weather than Hong Kong, Kaohsiung, or Chilung (Keelung). However, large combatants (CVA, cruisers, etc.) would find the relatively small size of Subic Bay restrictive. The cost in terms of time and money of evasion would be small since the evasion routes are short and direct. Smaller craft, given ample warning time, should also be able to evade into the navigable semicircle. If ample warning time is not given, or the means to evade does not exist, relatively safe typhoon anchorages are present in the inner basin of Port Olongapo for a limited number of small vessels. Also certain anchorages close to the western shore of the bay provide some degree of shelter.

3.1 GEOGRAPHICAL LOCATION

Figures VI-1 and VI-3 show the geographical location of Subic Bay on the island of Luzon. Subic Bay, centered near 14°50'N and 120°14'E, is approximately 4 n mi wide and 9 n mi long. The entrance to Subic Bay opens seaward to the southwest and Grande Island, located in the mouth of the bay, divides the entrance into two channels. The main channel, lying to the west of Grande Island is wide, deep, and clear of obstructions.

3.2 TOPOGRAPHY

Figure VI-3 depicts the topography of the terrain surrounding Subic Bay. The bay is surrounded by terrain in all directions except south-southwest. Peaks in excess of 4000 ft lie to the northeast and southeast, with passes through the mountains to the east-northeast and to the northwest of Subic Bay.

Figure VI-3 also depicts the bottom topography of Subic Bay. Depths decrease regularly from 200 ft in the entrance to 50 ft at its head. The greater part of the bay, including the Port Olongapo complex, has been swept to a depth of 49 ft. The entrance channel across Subic Bay and into the Port Olongapo complex is approximately 350 yards wide and has generally decreasing depths from 180 to 72 ft.

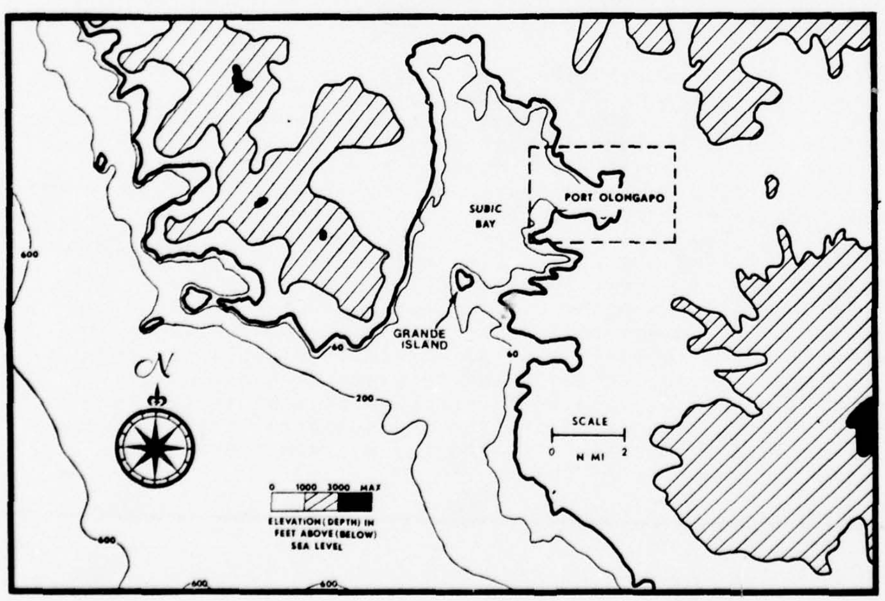


Figure VI-3. The Subic Bay area with topographical features of the surrounding terrain and bottom contours shown in feet. The area within the dotted outline is expanded and presented as Figure VI-4.

3.3 PORT OLONGAPO COMPLEX

Port Olongapo consists of an outer harbor and an inner basin (see Figure VI-4). The port complex is approximately 1 1/2 miles wide between Cubi Point and Kalaklan Point and extends about 1 1/2 miles eastward to the coast. The inner basin lies between Maritan Point and Rivera Point, with the Naval Supply Depot terminal pier extending from its northeast shore. The shore is extremely steep-to with little shoaling effect (the building in magnitude of waves when the water depth reaches one-half their wavelength) extending beyond a quarter mile offshore. Since Subic Bay is a U.S. Navy installation, all facilities are available for assignment to U.S. Navy vessels.

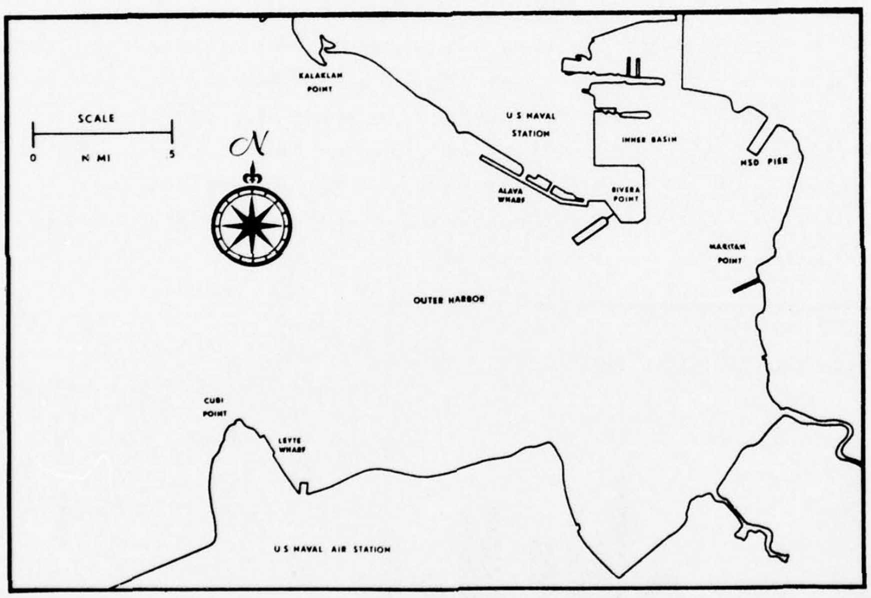


Figure VI-4. Port Olongapo showing the location of piers and wharves which are assigned to U.S. Navy ships.

3.4 HARBOR FACILITIES

There are 6 wharves and 2 piers which serve as primary berthing spaces for vessels entering the Port Olongapo complex. There are also 13 supplementary berths which are used for small craft only.

There are more than 160 anchorages in water depths of 70 to 150 ft with soft mud or coral bottom in Subic Bay. Mooring buoys for all sizes of ships are available and assigned by the Port Operations Officer (H.O. Pub. No. 918, 1974).

3.5 TROPICAL CYCLONES AFFECTING SUBIC BAY

3.5.1 Tropical Cyclones Climatology For Subic Bay

As Subic Bay is so close to Manila, the climatology of tropical cyclones for the two ports will be combined. For the purposes of this study, the midpoint (labeled point X in Figure VI-7) of a line connecting Manila Harbor and Port Olongapo was used. Point X is the center of a 180 n mi circle used to determine whether or not a tropical cyclone represents a threat (any tropical cyclone approaching within 180 n mi of point X is considered a threat) to the ports of Manila and Subic Bay. It is recognized that a few storms which did not approach within 180 n mi may have affected either or both ports. However, a reasonable criterion had to be chosen that would limit the size of the data sample.

Although tropical cyclones can occur at any time of the year, the majority of those which threaten Subic Bay and Manila occur in the months of June through December. Figure VI-5 depicts the monthly summary by 5-day periods of tropical cyclone occurrences based on data for the 19 years, 1955-1973. Of the 83 tropical cyclones that threatened Subic Bay and Manila, the peak threat periods exist in July, October, and November, but a consistent threat exists throughout the total June-December period.

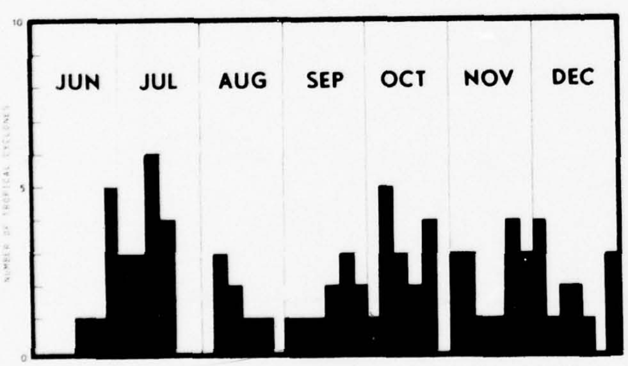
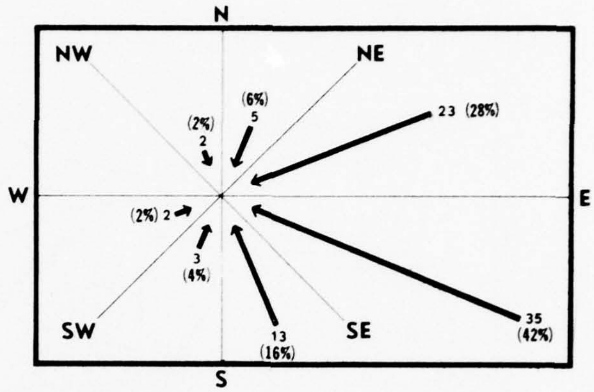


Figure VI-5. Frequency distribution of the number of tropical cyclones that passed within 180 n mi of point X. Subtotals are based on 5-day periods for tropical cyclones that occurred during 1955-1973.

Figure VI-6 displays the above storms as a function of the compass octant from which they approached point X. The numbers indicate the number of storms approaching from that octant, while the numbers in parentheses indicate the percentage of storms approaching point X from that octant. It is evident that the majority of storms approach Subic Bay and Manila from the east-southeast.

Figure VI-6. Direction of approach to point X of the tropical cyclones (1955-1973) that passed within 180 n mi of point X. Numbers indicate the number that approached from each octant. Number in parentheses is the percentage of the total sample (83) that approached from that octant.



Figures VI-7 to VI-13 present the percentage of tropical cyclones that have passed within 180 n mi of point X (can be interpreted as the probability of threat) for the months June to December, respectively. The solid lines represent the "percent threat" for any storm location. The dashed lines represent approximate approach times to point X based on an approach speed of 8-12 kt. For example, in Figure VI-7, a storm located at 130E and 10N has between a 60% and 80% probability of passing within 180 n mi of point X and it will reach point X in approxiamtely 2 1/2 days if its speed remains between 8-12 kt.

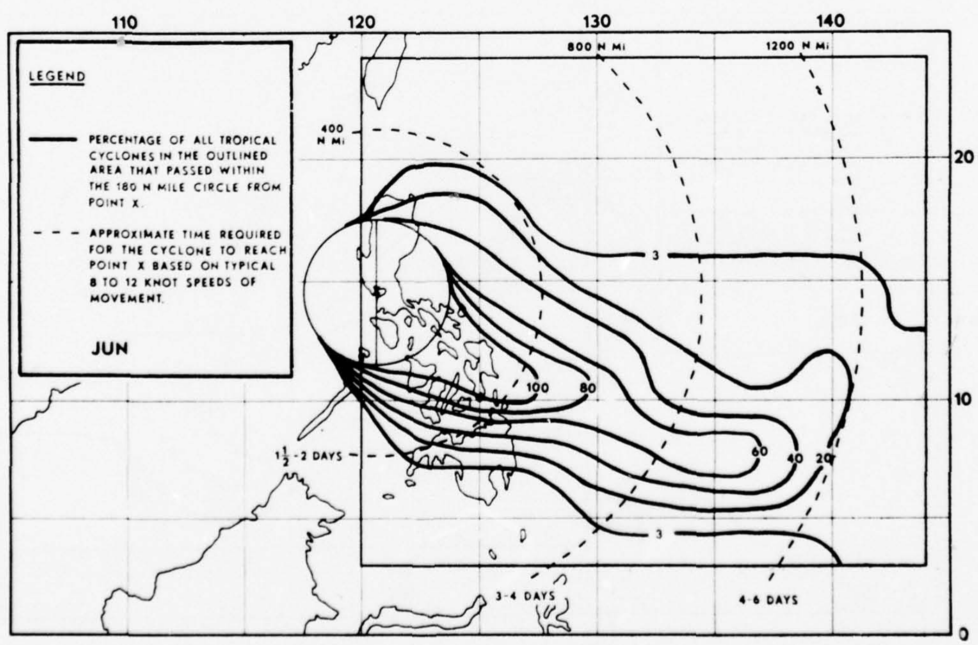


Figure VI-7. JUNE

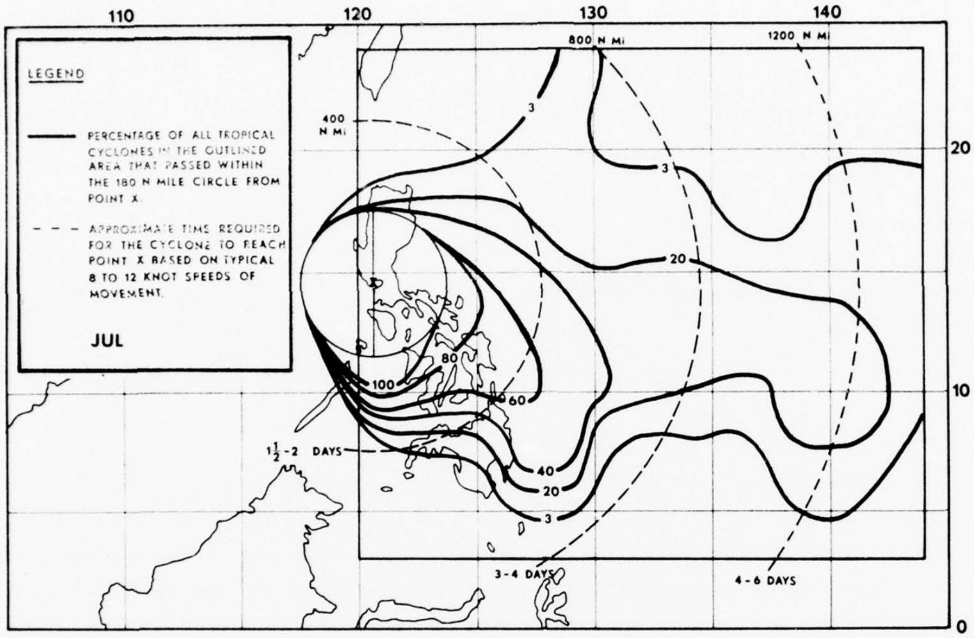


Figure VI-8. JULY

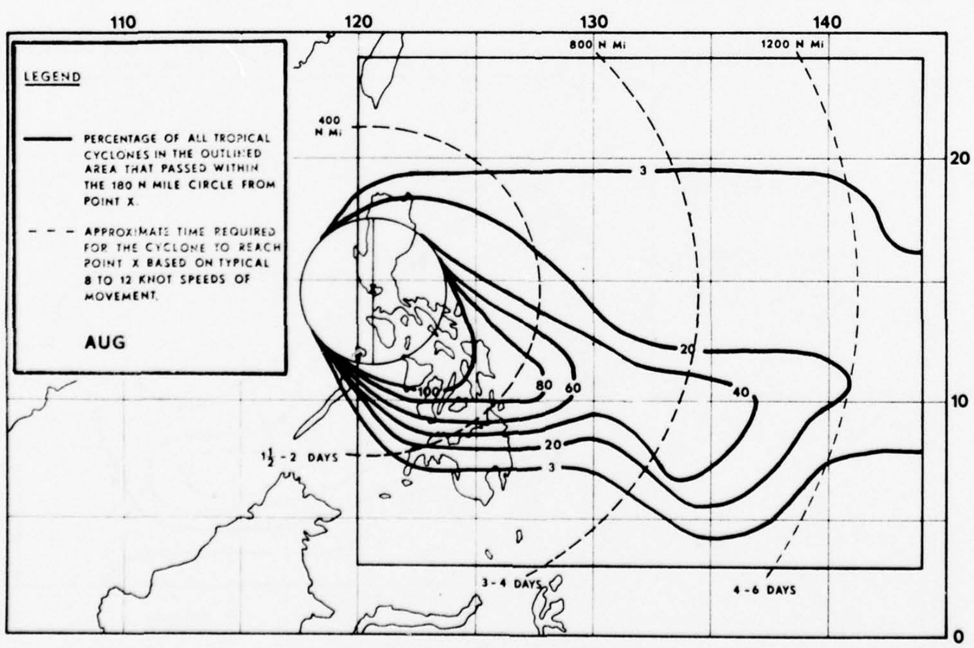


Figure VI-9. AUGUST

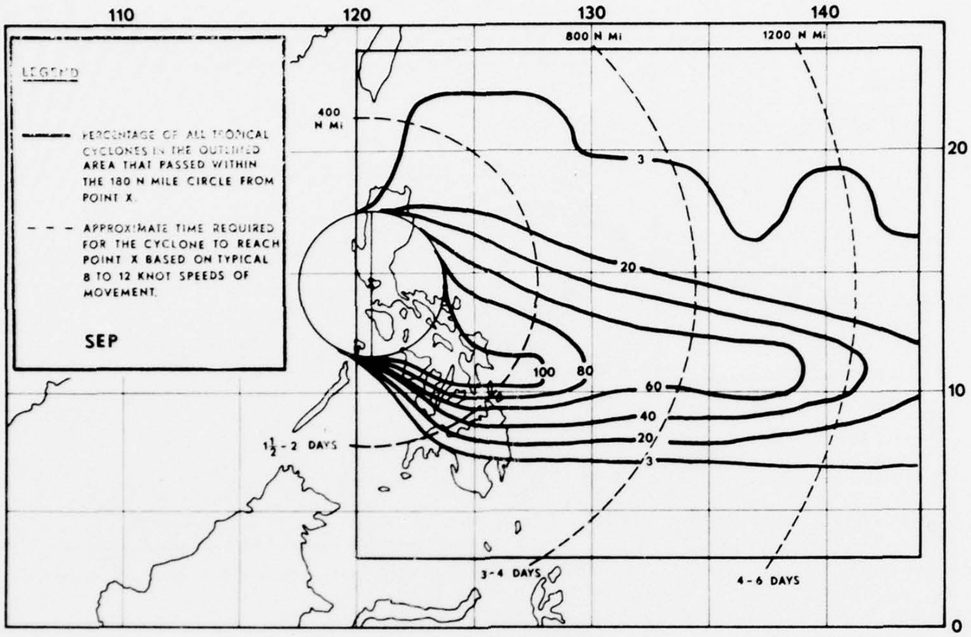


Figure VI-10. SEPTEMBER

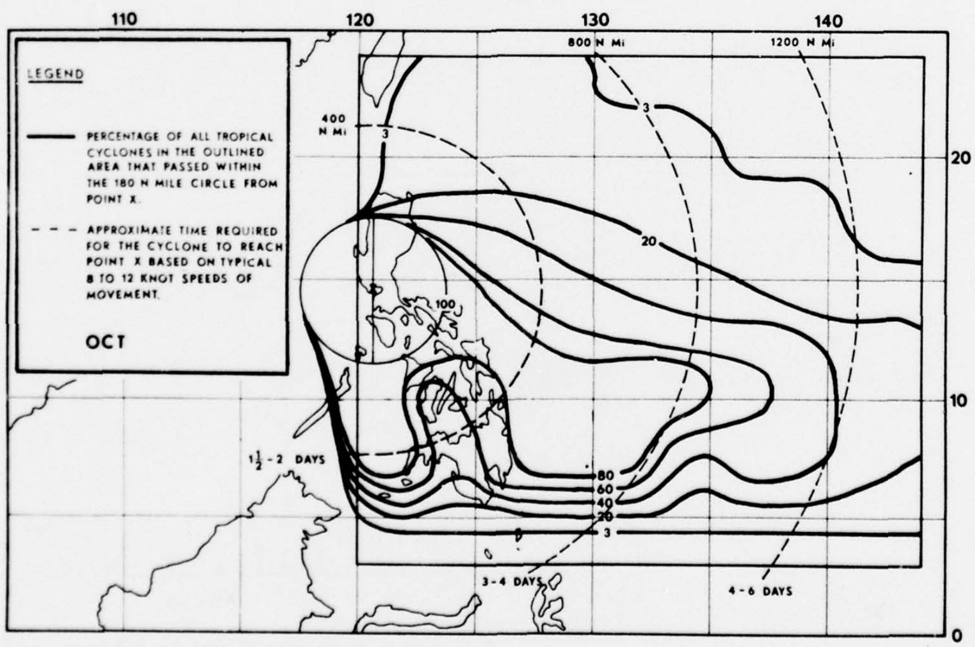


Figure VI-11. OCTOBER

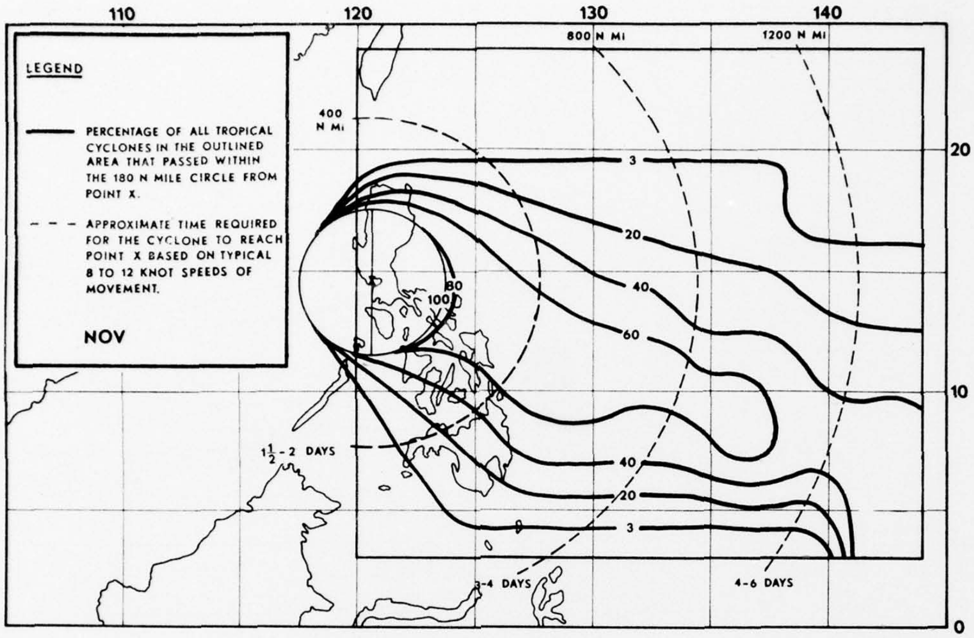


Figure VI-12. NOVEMBER

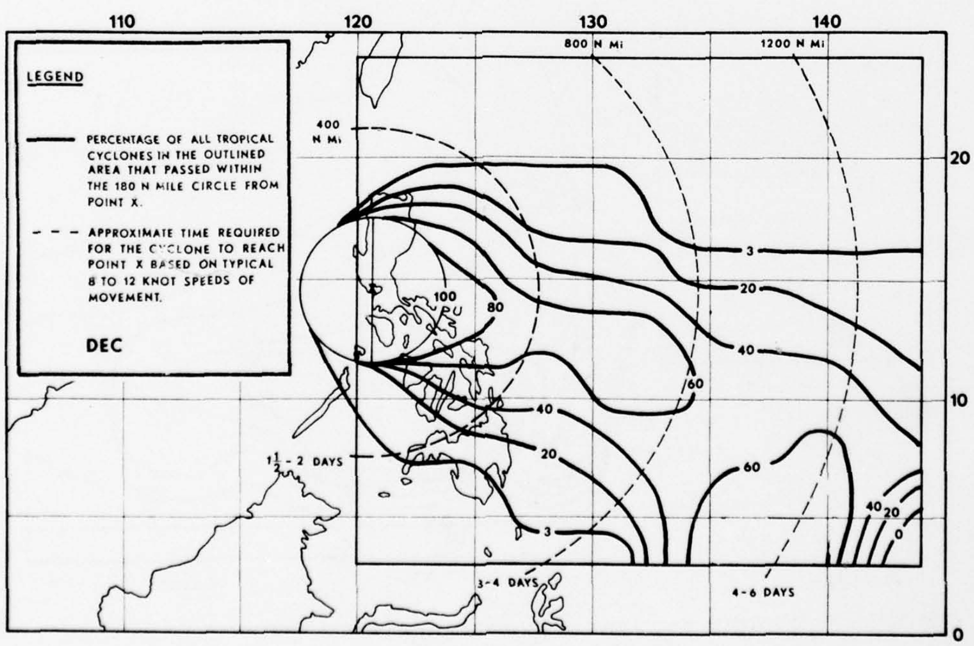


Figure VI-13. DECEMBER

3.5.2 Wind And Topographical Effects

In the 19-year period from 1955-1973, during the months June-December, a total of 83 tropical cyclones approached within 180 n mi of Subic Bay, which is more than four tropical cyclones per year.[1] Approximately 60% of this sample had their CPA to the north of Subic Bay, while 40% passed to the south. The largest number of tropical cyclones to threaten Subic Bay in any single year was 11 in 1964. Table VI-1 groups the above 83 tropical cyclones according to the wind intensity that they produced at Subic Bay. Of the 83 tropical cyclones concerned, 36% resulted in strong winds (≥22 kt) and only 13% resulted in gale force winds (≥34 kt).

Table VI-1. Extent to which tropical cyclones affected Subic Bay during the period June-December, 1955-1973.

Number of tropical cyclones that passed within 180 n mi of Subic Bay	83
Number of tropical cyclones resulting in strong (≥22 kt) winds at Subic Bay	30
Number of tropical cyclones resulting in gale force (≥34 kt) winds at Subic Bay	11

Wind data are from Naval Air Station, Cubi Point, but are not continuous for years 1955-1957 since wind observations were made only during station operating hours. The data are considered representative of the winds in Subic Bay in most situations. Due to the effect of the surrounding terrain, it is possible that winds from the SE quadrant will be of a lesser intensity at Cubi Point than over the Bay. It should be pointed out that because of the surrounding terrain around the Subic Bay area, it is very difficult to find a recording spot which is truly representative of the area. Note that wind comparisons made with ships tied up at both Alava and Leyte wharves suggest that the winds over the bay are, in general, 3-5 kt higher than that recorded over the Cubi Point runway. Also, the above wind data are reduced from hourly wind observations. It is possible, of course, that a high maximum sustained wind was observed for a short period of time between hourly observations and could not be included.

It is apparent from the results of Table VI-1 that the mountains surrounding Subic Bay (see Figure VI-3) serve as an effective wind barrier. For this reason, 56 kt is the highest sustained wind recorded there during the years 1955-1973.

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[1] From Chin (1972) for years 1955-1970 and from Annual Typhoon Reports for years 1971-1973 (U.S. FWC/JTWC, 1971-1973).

One recent example of Subic Bay's suitability as a haven follows: "Typhoon Irma passed Subic on Thanksgiving Day (28 Nov 1974). She made landfall on the Philippines at approximately 15.7N with winds of 90 kt with gusts to 110 kt, dipped southward in response to a building ridge and passed 30 n mi north of Subic with center winds of about 70-75 kt with gusts to 85 kt. Subic experienced maximum winds of 36 to 42 kt and gusts to 49 kt two hours after CPA" (U.S. NWSED, Cubi Point, 1974).

Typhoon Olga passed 40 n mi to the north of Subic Bay on 22 May 1976 and became almost stationary some 75 n mi to the NNW of Subic Bay for two additional days. The maximum sustained winds recorded at NAS Cubi Point was 35 kt (SW) with a maximum gust of 43 kt. The USS RANGER, at Alava Pier, reported maximum sustained winds of 48 kt (SW) with a peak gust of 60 kt. The RANGER also incurred winds over 30 kt for 49 hours and winds over 40 kt for 18 hours (anemometer height - 145 ft). The RANGER utilized two tugs, fore and aft, to breast off the pier during strong southwest winds and sustained no major damage. Typhoon Olga indicated that during periods of strong southwesterly winds, Alava and Rivera Piers are the worst possible mooring locations and NAS Cubi Point, although low lying, does provide considerable leeside shelter.

The arrows showing tropical cyclone movement in Figure VI-14 give the positions of tropical cyclone centers when the wind first and last exceeded 22 kt at Subic Bay. Figure VI-15 shows the position of tropical cyclone centers when the wind first and last exceeded 34 kt. Note that in most cases the tropical cyclones that affected Subic Bay with winds exceeding 22 kt passed to the north. In all instances, the onset of 22-kt winds did not occur until the tropical cyclones had approached within approximately 100 n mi of the eastern coast of the Philippines. On the other hand, tropical cyclones in the South China Sea more than 300 n mi from the west coast of the Philippines have produced 22-kt winds at Subic Bay. Note that most strong wind occurrences have happened with storms to the north and west of Subic Bay. However, the Naval Weather Service Environmental Detachment, Cubi Point strongly emphasizes that the tropical cyclones that have most severely affected Subic Bay (i.e., sustained winds or gusts over 50 kt) have had close passages (15-50 n mi) to the southwest (U.S. NWSED, Cubi Point, 1974). In addition the maximum sustained wind associated with a system passing within 50 n mi to the south has been from a northwesterly direction. A southward passage at distances greater than 50 n mi has usually resulted in winds from the east-northeast or southwest (U.S. NWSED, Cubi Point, 1974).

For a more detailed examination of the effects of tropical cyclones on Subic Bay, see Douglass, 1975.

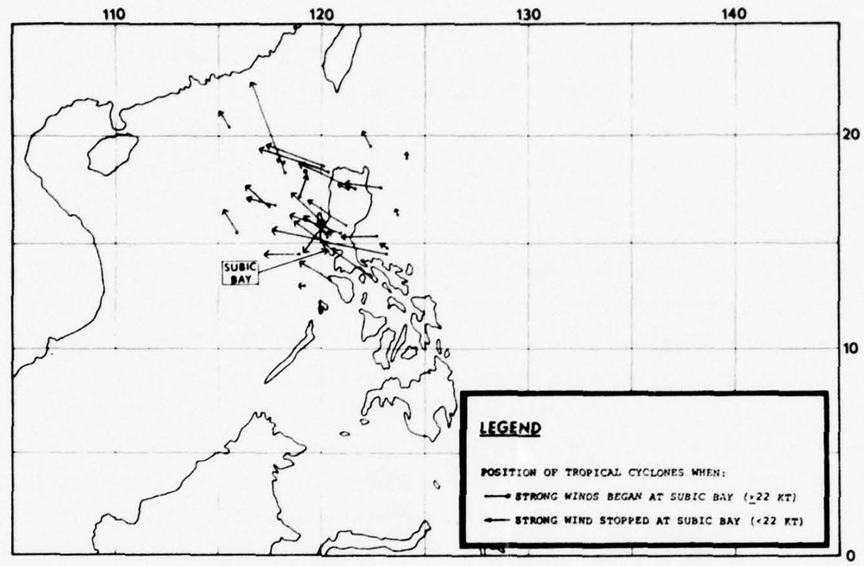

Figure VI-14. Positions of tropical cyclone centers when winds ≥22 kt first and last occurred at Subic Bay. (Based on data from 1955-1973.)

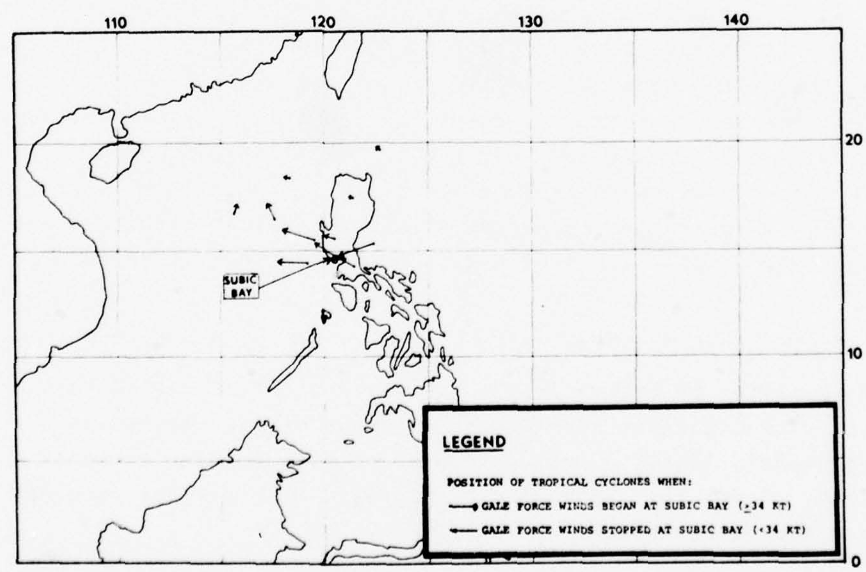

Figure VI-15. Positions of tropical cyclone centers when winds ≥34 kt first and last occurred at Subic Bay. (Based on data from 1955-1973.)

3.5.3 Wave Action

The largest waves in the vicinity of Subic Bay occur just outside the entrance of the bay. Examination of available wave data revealed that southwest monsoonal winds and typhoons in the South China Sea are responsible for the high wave conditions at the entrance to Subic Bay. Another contributing factor is the hydrography in the area, the predominant feature being the relatively deep water close to the entrance of Subic Bay and the reefs along the shorelines (see Figure VI-3). Although no direct observations have been recorded at Subic Bay, computational estimates (Johnson and Wiegel, 1955) indicate that significant wave heights of 32 ft and periods of 12 seconds could occur at the entrance to Subic Bay with the close passage of an intense typhoon.

The interior of Subic Bay is protected from significant wave action by the geography of the area, the southwest orientation of the bay, and the nearby hydrography. Only waves from the southerly or westerly directions have any effect on the interior of Subic Bay. These waves enter the bay, but reach interior points only by refraction around the east or west sides of Grande Island, and are of little significance.

The NWSED ,Cubi Point (U.S. NWSED, Cubi Point, 1974) points out the following:

"Typically, when a westward moving typhoon is approaching the Philippines, ships will start evasion when the cyclone is still 24 to 12 hours away from CPA. At that time, bay conditions will be light, but there may be 9-12 seas in the South China Sea and 5-7 ft seas at the entrance to the bay. Such seas that must be overcome to depart the bay are of major importance to most ships. Also once a ship has left the bay and is evading south, the sea in most cases will be a following type as far south at 10-12N. Most of the South China Sea swell is due to the increased pressure gradient between the cyclone and the ridge over China. The swell train of the cyclone is cut off by the Philippines."

3.5.4 Storm Surge And Tides

Examination of charts from a now defunct portable tide gage and conversations with engineers revealed no evidence of storm surge in Subic Bay (Johnson and Wiegel, 1955). Tidal currents in Subic Bay are variable and generally weak. Tides are predominantly diurnal, with a tidal range of 3.1 ft (average) and 6.0 ft (extreme).

3.6 THE DECISION TO EVADE OR REMAIN IN PORT

3.6.1 General

Refer to paragraphs 6 and 7 of Chapter I which describes warning procedures and services. Also refer to appropriate instruction concerning local heavy weather readiness conditions.

3.6.2 Remaining In Port

Remaining in port when the means to evade a storm is available is a decision that is contrary to most of the traditional rules of seamanship. However, if the decision to remain in port is made, it should not be made without considering every available fact concerning the impending storm and the port in which the vessel is berthed. In the case of Port Olongapo in Subic Bay the following points should be noted:

1. Securing to a pier or anchoring in the bay should be done prior to the onset of 22-kt winds to prevent undue difficulty in mooring.

2. No berths in Port Olongapo can be considered totally sheltered.

3. Once the decision to remain in port has been made, any reversal in plans would be extremely dangerous. Subic Bay is a relatively sheltered harbor so any wave and wind actions would be much more severe outside the entrance to the bay and in the open sea.

4. The holding action of the mud and coral bottom is considered good and the risk of ships breaking loose in heavy weather is lower in Subic Bay than in many other WESTPAC ports.

3.6.3 Evasion

When evasion of a tropical cyclone is being contemplated the importance of correctly assessing the threat posed by the storm and acting quickly so as to retain flexibility cannot be overemphasized. The following time table, depicted in Figure VI-16 has been set up for this purpose:

1. There is an existing tropical cyclone, or potential development in Area C, with movement toward Subic Bay forecast:

   a. Review the material condition of the ship; sailing within 2-4 days is a distinct possibility.

   b. Reconsider all maintenance activities scheduled to exceed 48 hours.

2. A tropical cyclone has entered Area B with movement toward Subic Bay forecast:

   a. Operational plans should be made in the event sortie is ordered.

   b. Reconsider all maintenance activities scheduled to exceed 24 hours.

3. A tropical cyclone has entered Area A with movement toward Subic Bay forecast:

   a. Execute evasion plans made in previous steps.

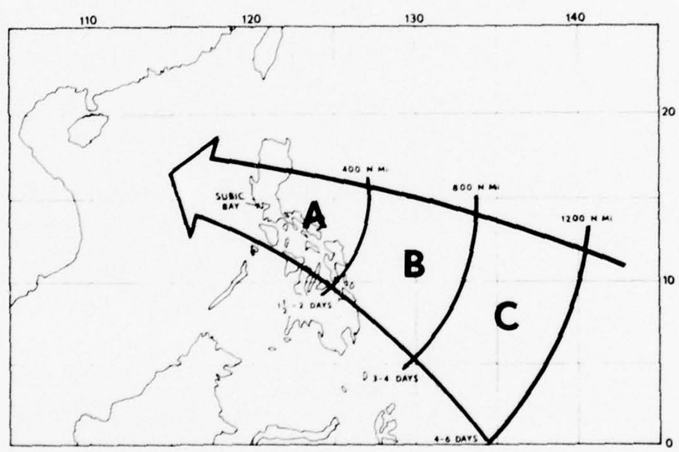

Figure VI-16. Tropical cyclone threat axis for Subic Bay. Distances and approach times are measured from Subic Bay, based on an 8-12 kt speed of movement.

Whatever evasion decision is made, the following general comments should be considered.

1. When departing Subic Bay, ample time should be given to combat the heavy sea condition likely to be encountered at the entrance to Subic Bay.

2. Crossing ahead of a typhoon should be accomplished well in advance. Heavy swells may be encountered ahead of an advancing typhoon long before the occurrence of strong winds. Such swells may decrease a ship's maneuverability and speed of advance, preventing avoidance of the typhoon track.[2]

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[2] See paragraph 5, Chapter I for discussions and examples of the extent to which sea state and wind speed reduce the speed of advance of a vessel.

3. At certain times of the year, particularly in the peak typhoon season, the possibility exists that two or more tropical storms will be present at one time. This will greatly complicate any evasion planning and execution.

4. A looping tropical cyclone can cause a false sense of security as evading ships attempt to return. A looping storm in the South China Sea after initial passage can regenerate and cause as high or higher winds/seas upon its return.

3.6.4 Evasion Techniques

The final decisions involving evasion of tropical cyclones rest with the commanding officer of the vessel involved. One of the more successful Pacific Ocean evasion techniques involves running downwind and downsea relative to the typhoon in order to reach a latitude south of the storm and in the navigable semicircle. The success of this method depends upon almost continuous reconnaissance coverage and the relatively slow movement and gradual expansion of the initially small area affected by severe winds which is characteristic of typhoons at low latitudes.

For a ship in or near Subic Bay the following evasion techniques for the more common threat situations (any tropical cyclone expected to have a CPA within 180 n mi) are suggested:

1. Tropical cyclone forecast to pass north of Subic Bay:

   a. Evasion should be to the west-southwest since units are already in the navigable semicircle and will remain there.

2. Tropical cyclone forecast to pass east of Subic Bay:

   a. Evasion should be to the west-southwest since an eastward passing tropical cyclone may have already started recurvature and a westward heading will keep the ship in the navigable semicircle.

3. Tropical cyclone forecast to pass south of Subic Bay:

   a. Evasion should be to the west-southwest. This decision should be made as early as possible in order to avoid meeting the storm.

It should be noted that some tropical cyclones do generate in the South China Sea each year. However, their normal tracks are to the west and/or north and should not present a threat to units in the Subic Bay area (refer to Appendix 1-A).

In all cases careful monitoring of the storm should be conducted to permit the utilization of the proper evasion technique in the event of a sudden change in storm track.

4. MANILA

SUMMARY

It is the conclusion of this study that Manila Harbor is not a safe harbor and Manila Bay is not a safe refuge during a passage of a typhoon. The policy of the Port Captain of the South Harbor, Manila, is to evacuate all vessels at least 24 hours prior to typhoon passage. The harbor is extremely busy and congested with primarily merchant and commercial shipping vessels. These vessels are, more often than not, equipped with inadequate or inferior mooring equipment and they may evacuate to any area in Manila Bay outside the confines of South Harbor. Because of the danger of ships breaking loose from anchor during the storm (poor holding) and the shallowness of the bay, it is recommended that all U.S. Navy or contracted DOD vessels sortie from Manila Bay as well as from Manila Harbor. Since the evasion route is generally southwesterly into the South China Sea, the sortie should be relatively short, low in operating costs, and free of peril.

4.1 GEOGRAPHICAL LOCATION AND GENERAL DESCRIPTION

Manila is the largest city in the Philippine Islands and is located on the eastern shore of Manila Bay (see Figure VI-17). Manila Bay is approximately 26 n mi long, 19 wide at its widest point, and includes an area of about 550 square miles. The entrance to Manila Bay is divided into two channels by Corregidor and Caballo Islands. These channels are named North Channel and South Channel, and both are deep and clear of obstructions.

4.2 TOPOGRAPHY

Figure VI-17 depicts some of the topographical features surrounding Manila and Manila Bay. The Sierra Madre mountains to the east and the mountains of the Bataan Peninsula help to shelter Manila Bay from severe winds.

Figure VI-18 depicts the bottom topography of Manila Bay. The depths of Manila Bay range from over 180 feet in the entrance to about 90 feet in the center, decreasing gradually to the shore. Note that the bay is very shallow in some places and has relatively poor holding action due to its sand and soft mud bottom.

4.3 MANILA HARBOR

The port of Manila consists of the North and South Harbors, both of which are protected by breakwaters. Figure VI-19 is a diagram of Manila Harbor, showing the South Harbor only. The Pasig River separates the two harbors and is navigable to a distance of one mile from its mouth by small vessels drawing up to 10 feet. The North Harbor is the smaller of the two harbors and is used solely for inter-island shipping. The South Harbor is used for large ocean-going vessels and is the harbor that will be considered in this study.

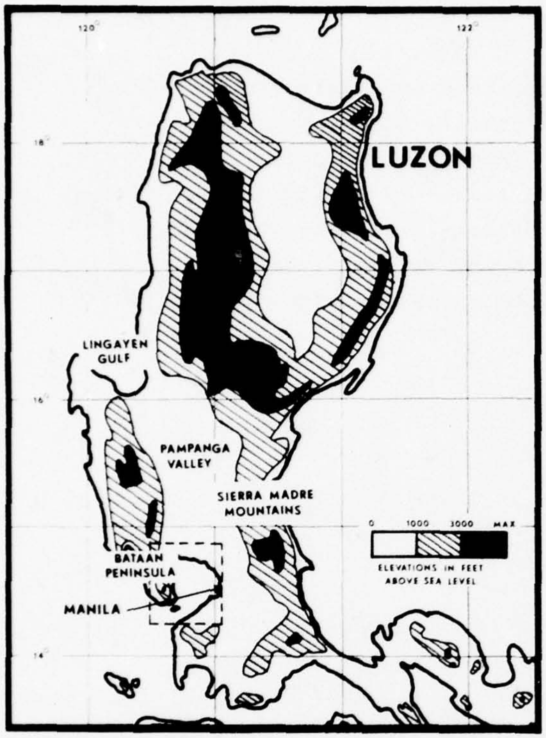

Figure VI-17. Topographical map of Luzon showing approximate elevation above sea level and the location of Manila. The area within dotted outline is expanded and presented in Figure VI-18.

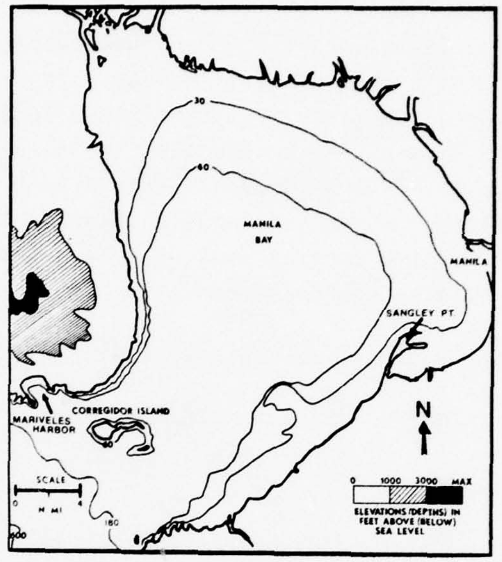

Figure VI-18. Depth contours in Manila Bay (ft).

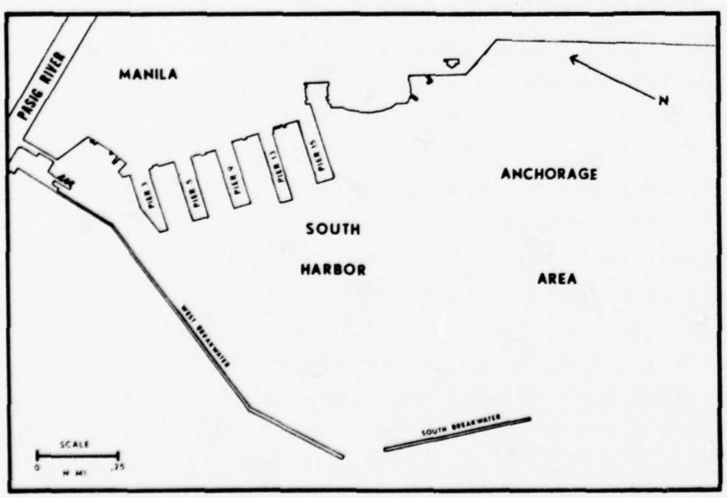

Figure VI-19. Manila Harbor plan showing the location of piers and anchorage areas which can be assigned to U.S. Navy and contracted DOD vessels.

4.4 HARBOR FACILITIES

There are five odd-numbered piers that extend southeastward from the northern side of South Harbor. These piers contain the principal deep-draft berths and range in depth from 9 to 36 ft. There are anchorages, both inside and outside the breakwater, for an unlimited number of vessels of all classes. The anchorages range in depth from 8 to 22 fathoms with less than adequate holding ground. It should be noted that with the return of NAS Sangley Point to Philippine control, U.S. Navy and DOD contract vessels no longer are assigned special anchorage areas.

4.5 TROPICAL CYCLONES AFFECTING MANILA

4.5.1 Tropical Cyclone Climatology for Manila

Refer to paragraph 3.5.1 of Chapter VI for the tropical cyclone climatology of Manila.

4.5.2 Wind And Topographical Effects

In the 19-year period from 1955-1973, for the months June-December, a total of 83 tropical cyclones approached within 180 n mi of Manila.[3] (Approximately 60% of this sample had their CPA to the north of Manila, while 40% passed to the south.) This is an average of more than four tropical cyclones per year. The largest number of tropical cyclones approaching Manila in any single year was eleven in 1964. Table VI-2 groups the above 83 tropical cyclones according to the wind intensity that they produced at Manila. Of the 83 tropical cyclones concerned, 28.5% resulted in strong winds ($\geq$22 kt) at Manila and only 8.4% resulted in gale force winds there ($\geq$34 kt).

The wind data for Manila is from NAS Sangley Point for years 1955-1968. For the remaining years, 1969-1973, the data were taken from a wind gage at the mouth of the Pasig River and are verified to be representative of the wind in Manila Bay. It should be noted the above wind data are reduced from hourly wind observations. There are situations, of course, in which a high maximum sustained wind was observed for a short period of time between hourly observations and could not be included.

It is apparent from Table VI-2 that Manila must be a sheltered harbor. Figure VI-17 depicts the sheltering effect of the terrain surrounding Manila. The Sierra Madre mountains to the east and the Bataan Peninsula to the west effectively serve as a wind barrier. When gale force winds do appear they are generally funneled from the Lingayen Gulf through the Pampanga Valley to Manila.

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[3] From Chin (1972) for years 1955-1970 and from Annual Typhoon Reports for 1971-1973 (U.S. FWC/JTWC, 1971-1973).

Table VI-2. Extent to which tropical cyclones affected Manila during the period June-December, 1955-1973.

Number of tropical cyclones that passed within 180 n mi of Manila	83
Number of tropical cyclones resulting in strong winds (≥22 kt) at Manila	24
Number of tropical cyclones resulting in gale force winds (≥34 kt) at Manila	7

Figure VI-20 shows the position of tropical cyclone centers when the wind first and last exceeded 21 kt at Manila. Figure VI-21 shows the positions of tropical cyclone centers when the wind first and last exceeded 33 kt at Manila. Notice that the relatively few tropical cyclones resulting in gale force winds at Manila began affecting the port very close to, or after, tropical cyclone passage (see Figure VI-21). Those tropical cyclones resulting in strong winds (≥22 kt) did not affect Manila until the cyclone centers were very close to the east coast of the Philippines, but tropical cyclones several hundred miles to the west of the Philippines still had an effect on the winds experienced at Manila (see Figure VI-20).

For a more detailed discussion on the effects of tropical cyclones on Manila Harbor, see Douglass, 1975.

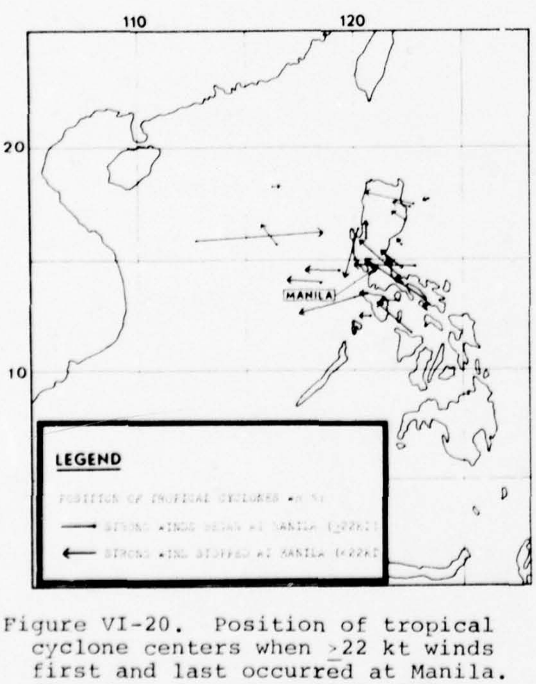

Figure VI-20. Position of tropical cyclone centers when ≥22 kt winds first and last occurred at Manila. (Based on data from 1955-1973.)

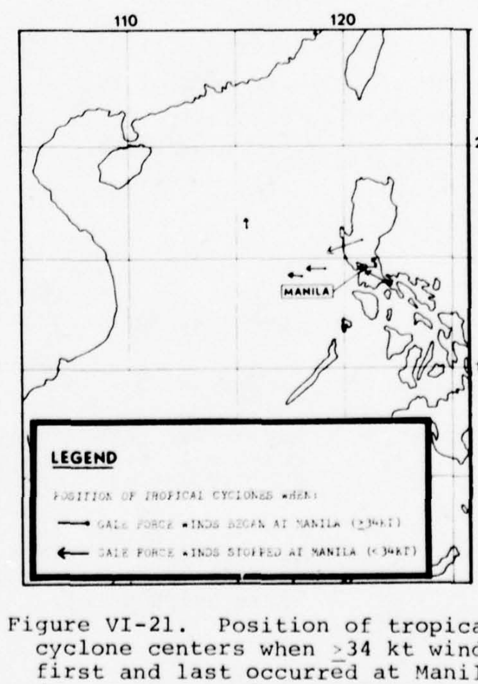

Figure VI-21. Position of tropical cyclone centers when ≥34 kt winds first and last occurred at Manila. (Based on data from 1955-1973.)

4.5.3 Wave Action

Quantitative information on wave height data for Manila Harbor or Manila Bay is not readily available. However, strongest winds are experienced in the bay when a typhoon is near or over the Lingayen Gulf and funneling winds occur through the Pampanga Valley to Manila. These strong north-northwesterly winds present more of a hazard to ships in the bay than do the waves they generate. Due to the relatively short fetch and shallow bottom, the generated waves could reach ten feet or more in significant height but should not build to excessively high levels.

The swell coming into the bay is damped considerably by Corregidor Island which sits in the mouth of the bay. It serves to split the swell and deflect it to either side. The possibility of shoaling (the building in magnitude of waves when the water depth reaches one-half their wavelength) occurs when the deflected swell reaches the shallower portions of the bay.

4.6 THE DECISION TO EVADE OR REMAIN PORT

4.6.1 General

For general information about tropical cyclone warnings and services the reader is referred to paragraphs 6 and 7 of Chapter I. Also refer to appropriate instructions concerning local heavy weather conditions.

4.6.2 Remaining In Port

Remaining in port when it is possible to evade a storm is a decision that is contrary to most of the traditional rules of seamanship. However, if the decision to remain in port is made, it should not be done without considering every available fact concerning the impending storm and the port in which the vessel is berthed. In the case of Manila Harbor the following should be noted:

1. Securing to a pier or anchoring in Manila Bay should be done prior to the onset of 22-kt winds to prevent undue difficulty in mooring.

2. No berths in Manila Harbor can be considered totally sheltered.

3. Manila Bay is extremely shallow in places and has relatively poor holding ground since the bottom consists of soft mud and sand.

4. Mariveles Harbor (see Figure VI-18) is the most secure harbor in times of weather stress, but it is only large enough to accommodate two or three ships safely.

5. South Harbor in Manila Harbor is a crowded harbor and at any given time can contain many merchant ships. Some of these vessels may be equipped with inadequate or poorly maintained mooring gear. As a result, it is not uncommon for them to break loose and cause damage to other ships in port.

4.6.3 <u>Evasion</u>

When evasion of a tropical cyclone is being considered, the importance of correctly assessing the threat posed by the storm and acting quickly so as to retain flexibility cannot be overemphasized. The following timetable, depicted in Figure VI-22, has been constructed for this purpose:

1. There is an existing tropical cyclone, or potential development in Area C, with movement forecast toward Manila:

    a. Review the material condition of the ship; sailing within 2-4 days is a distinct possibility.

    b. Reconsider all maintenance activities scheduled to exceed 48 hours.

2. A tropical cyclone has entered Area B with movement toward Manila forecast:

    a. Operational plans should be made in the event sortie is ordered.

    b. Reconsider all maintenance activities scheduled to exceed 24 hours.

3. A tropical cyclone has entered Area A with movement toward Manila forecast:

    a. Execute evasion plans made in previous steps.

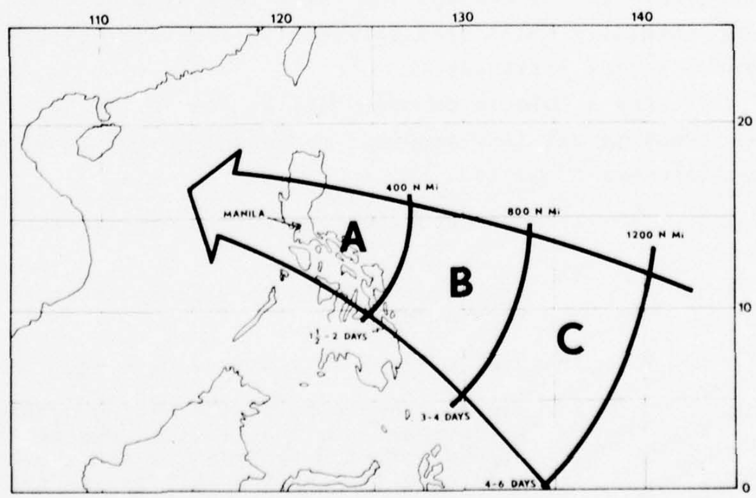

Figure VI-22. Tropical cyclone threat axis for Manila. Distances and approach times are measured from Manila, based on an 8-12 kt speed of movement.

Whatever evasion decision is made, the following general comments should be considered.

1. Even weak typhoons crossing the Philippine Islands can quickly result in strong winds in Manila Bay. The decision to sortie should be made far enough in advance to preclude difficulties in exiting Manila Bay.

2. Crossing ahead of a typhoon should be accomplished well in advance of the approaching typhoon. Heavy swells may be encountered ahead of the advancing typhoon considerably before the occurrence of strong winds. Such swells may decrease a ship's maneuverability and speed of advance, preventing clearance of the typhoon track (see paragraph 5, Chapter I).

3. At certain times of the year, particularly the peak typhoon season, the possibility exists that two or more tropical storms are present. This would greatly complicate any evasion planning and execution.

4. A looping tropical cyclone can cause a false sense of security as evaded ships attempt to return. A looping storm in the South China Sea after initial passage can regenerate and cause as high or higher winds/seas upon its return.

4.6.4 Evasion Techniques

The final decision involving evasion of tropical cyclones rests with the commanding officer of the vessel involved. One of the more successful Pacific Ocean evasion tactics involves running downwind and down sea relative to the tropical cyclone in order to reach a latitude south of the storm and in the navigable semicircle. The success of this method requires almost continuous reconnaissance coverage and the relatively slow movement and gradual expansion of the initially small area affected by severe winds that is characteristic of typhoons at low latitudes.

For a ship in or near Manila, the following evasion techniques for the more common threat (any tropical cyclone expected to have a CPA within 180 n mi) situations are suggested.

1. Tropical cyclone forecast to pass north of Manila:

   a. Evasion should be to the west-southwest since units are already in the navigable semicircle and will remain there.

2. Tropical cyclone forecast to pass east of Manila:

   a. Evasion should be to the west-southwest since an eastward passing tropical cyclone may have already started recurvature and a westward heading will keep the ship in the navigable semicircle.

3. Tropical cyclone forecast to pass south of Manila:

   a. Evasion should be to the west-southwest. This decision should be made as early as possible to preclude a rendezvous with the storm.

It should be noted that some tropical cyclones do generate in the South China Sea each year. However, their normal tracks are to the west and/or north and should not present a threat to units in the Manila area (refer to Appendix 1-A).

In all cases, careful monitoring of the storm should be conducted to permit the proper evasion technique to be employed in the event of a sudden, unpredicted change in track by the storm.

5. CEBU

SUMMARY

H.O. Pub. No. 91, Sailing Directions for the Philippine Islands, describes Cebu City as an ideal harbor with safe anchorages and protected from winds from all sides. However, interviews with harbor officials revealed that extensive damage has occurred within the confines of the harbor as a direct result of close passages of typhoons. Harbor officials cited the passage of Typhoon Amy which produced sustained winds up to 85 kt on 10 December 1951, resulting in the destruction of seven inter-island vessels. Also cited were instances where larger vessels (none larger than U.S. Destroyer class) dragged anchor in the outer harbor under much lighter winds. Other key factors that make Cebu City less than desirable as a typhoon haven are:

1. Maneuvering is severely restricted within the harbor. (Use of the inner harbor is not recommended and is restricted during winds above approximately 12 kt, during ebb tide or during the event of tropical cyclone-associated tides.)

2. The threat of other vessels adrift in the confined harbor.

3. The likely absence of sheltered berths for U.S. ships within the inner harbor due to overcrowding by inter-island vessels.

After considering the above facts and the many discussions with experienced personnel at Cebu City, it is the conclusion of this study that, although Cebu City does afford relatively good shelter in the majority of typhoon passages, it should not be considered an "unqualified" typhoon haven. Larger combatants (cruiser, etc.) would find the size and obstructions severely restrictive. The cost in terms of time and money of evasion would be small since the evasion routes are short and relatively direct. Smaller craft, given ample warning time, should also be able to evade into the navigable semicircle. If ample warning time is not given, or the means to evade does not exist, only limited, relatively safe anchorage is present for a limited number of small vessels. Since inter-island vessels occupy virtually all the inner harbor berths and anchorages suitable for U.S. craft, assignment will likely be made to south anchorage.

5.1 GEOGRAPHICAL LOCATION

Figures VI-1 and VI-23 show the geographical location of Cebu City on the island of Cebu. Cebu City, the capitol of the province of the same name, is the second largest city in the Archipelago and is a port of entry. Figure VI-24 shows Cebu Harbor, one of the finest in the Philippines, formed by the strait between Cebu and Mactan Island, centered about 10°20'N and 123°55'E.

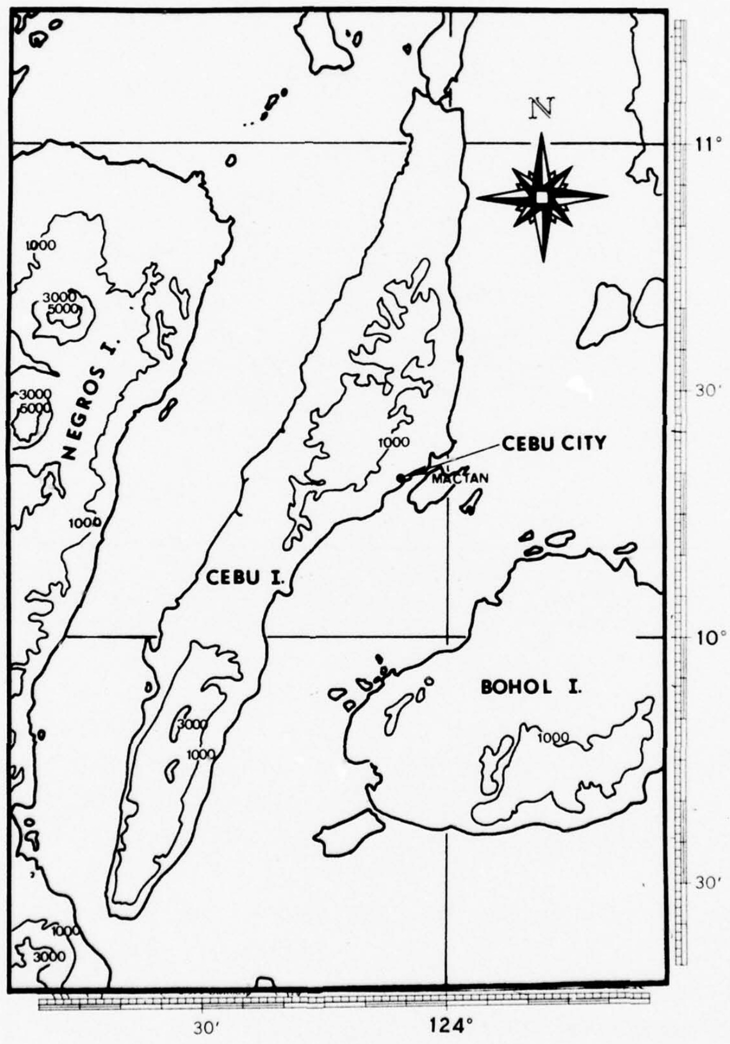

Figure VI-23. Area map showing location of Cebu City and topographical features of the surrounding terrain (elevations in ft).

Chg 1

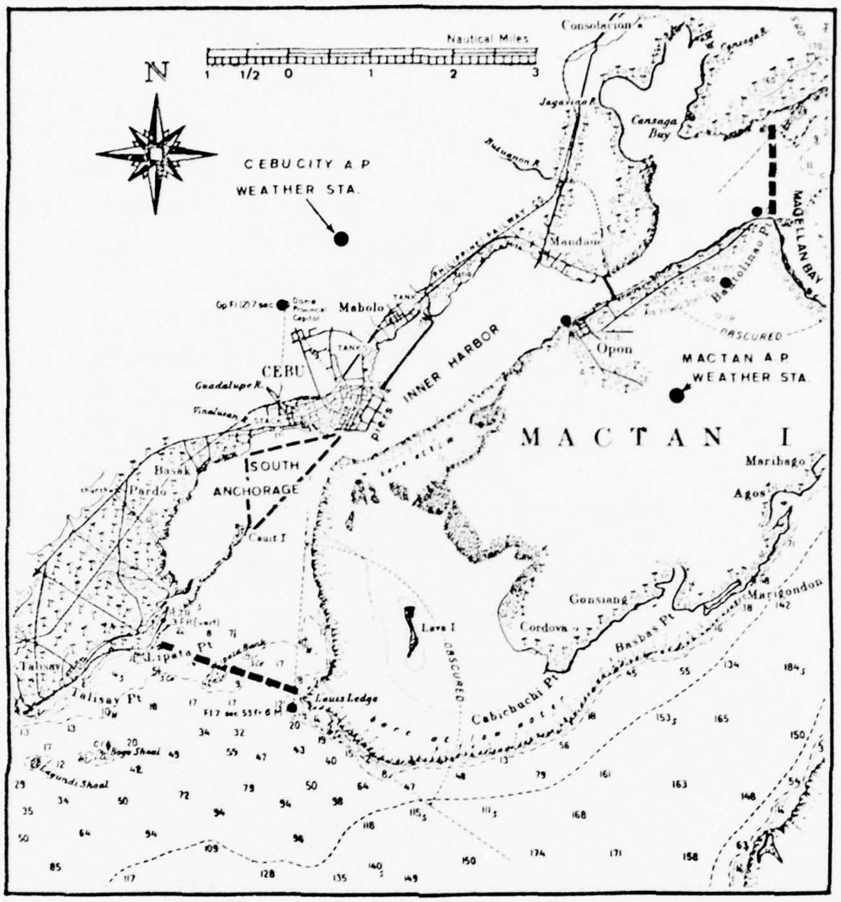

Figure VI-24. Map of Cebu Harbor showing the outer limits (▬▬▬), the inner harbor, south anchorage (— — —) and location of Cebu and Mactan Weather Stations (soundings in fathoms).

5.2 CEBU HARBOR

Limits of the harbor (Figure VI-24) are defined by a line extending from Bantolinao Point on the northern tip of Mactan Island, due north to the mainland of the island of Cebu and a line extending from Lauis Ledge on the southwestern tip of Mactan Island to Lipata Point on Cebu. Pilotage is compulsory within the harbor limits.

Cebu Harbor can be entered from the south. The northeast channel is narrow and heavily congested, having a least navigable width of 150 yards and a controlling depth of 26 feet. A bridge connects Mactan Island to the mainland with vertical clearance of 89 feet (Figure VI-24).

U.S. Navy ships are generally assigned anchorage in the south anchorage zone located in the outer harbor (Figure VI-24). All vessels drawing more than 8 feet are advised to anchor within the limits of the south anchorage zone.

The inner harbor is used by inter-island vessels and is not recommended for usage by U.S. Navy ships at any time. The following information was received firsthand from Capt. Pablo J. Pido, PN (ret), Chief Pilot of Cebu, with over 40 years experience in Cebu Harbor: Cebu Harbor should not be considered as a storm haven for U.S. Navy ships. Within the inner harbor, holding is not good, and manuevering is restricted during ebb tide or during storm conditions. As an additional word of caution, maneuvering has also been found to be restricted with winds greater than 12 knots. The south anchorage area was reported to be restrictive to maneuvering, to have a mud bottom, to be inadequately protected from high winds out of the south, and to lack typhoon buoys.

5.3 TOPOGRAPHY

Figures VI-1 and VI-23 indicate that Cebu Harbor is generally well protected from direct passage of most major tropical cyclones by the general topography of the island group. In close proximity, it is well screened from the southwest through northwest by the topography of the island of Cebu that rises rapidly to elevations approaching 3,000 feet some seven miles inland. Farther southward, mountains rise steeply to 1,000 feet within one to three miles of the shore. Immediately adjacent, Mactan Island is less than 100 feet high, generally eight to ten feet, thereby offering minimal protection from high winds of an easterly origin. However, some protection from this direction is afforded by the island of Bohol to the southeast with elevations rising to 3,000 feet.

5.4 HARBOR FACILITIES

For a detailed description of harbor facilities available in Cebu, the reader is referred to CINCPACFLT Port Directory or H.O. Publication No. 91, Sailing Directions for the Philippine Islands.

5.5 TROPICAL CYCLONES AFFECTING CEBU HARBOR

5.5.1 Tropical Cyclone Climatology for Cebu

For the purposes of this study, any tropical cyclone approaching within 180 n mi of Cebu City is considered a "threat" to the port. It is recognized that a few tropical cyclones which did not approach within 180 n mi may have affected Cebu. However, a reasonable criterion had to be chosen that would limit the size of the data sample.

CEBU

Although tropical cyclones occur throughout the year, the majority of those which threaten the harbor of Cebu occur in the months of June through December. Figure VI-25 depicts the monthly summary of tropical cyclone occurrences based on data for the 28 years 1947-74. Of the 69 tropical cyclones that threatened Cebu in this 28-year period (more than two threats per year), the peak threat periods exist in October, November and December but a consistent threat exists throughout the total June-December period.

Figure VI-26 displays the above storms as a function of the compass octant from which they approached Cebu. It is evident that the majority of storms generally approach Cebu from the east, and primarily from the east-northeast.

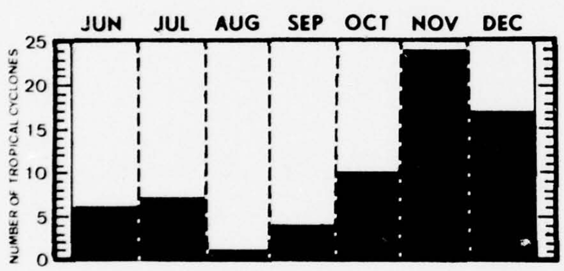

Figure VI-25. Frequency distribution of the number of tropical cyclones that passed within 180 n mi of Cebu (June-December, 1947-74).

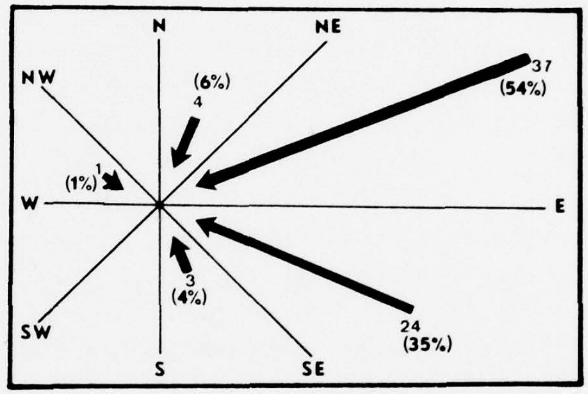

Figure VI-26. Direction of approach to Cebu of the tropical cyclones (June-December, 1947-74) that passed within 180 n mi. Open numbers indicate the number that approached from each octant. Percentages in ( ) are the percentage of the total sample (69) that approached from each octant.

Figures VI-27 to VI-33 are analyses of tropical cyclones that passed within 180 n mi of Cebu during the period 1947-74. The solid lines represent the "percent threat" for any storm location. The dashed lines represent approximate approach times to Cebu based on an approach speed of 8-12 kt. For example, in Figure VI-27, a storm located at 135E and 10N has approximately a 60% probability of passing within 180 n mi of Cebu and will reach Cebu in less than three days if its speed remains between 8-12 kt.

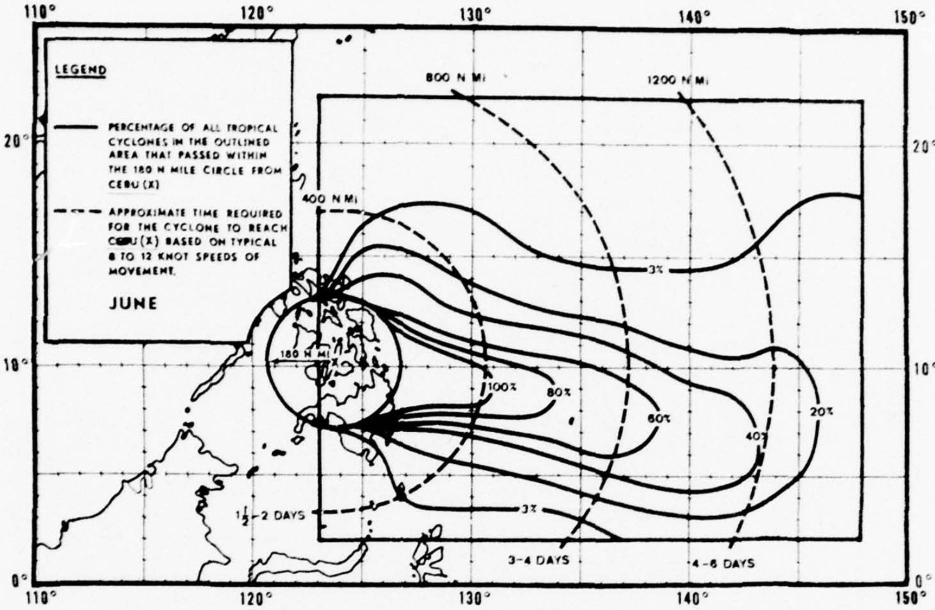

Figure VI-27. Probability that a tropical cyclone will pass within 180 n mi of Cebu (X) for the month of June (based on data from 1947-74).

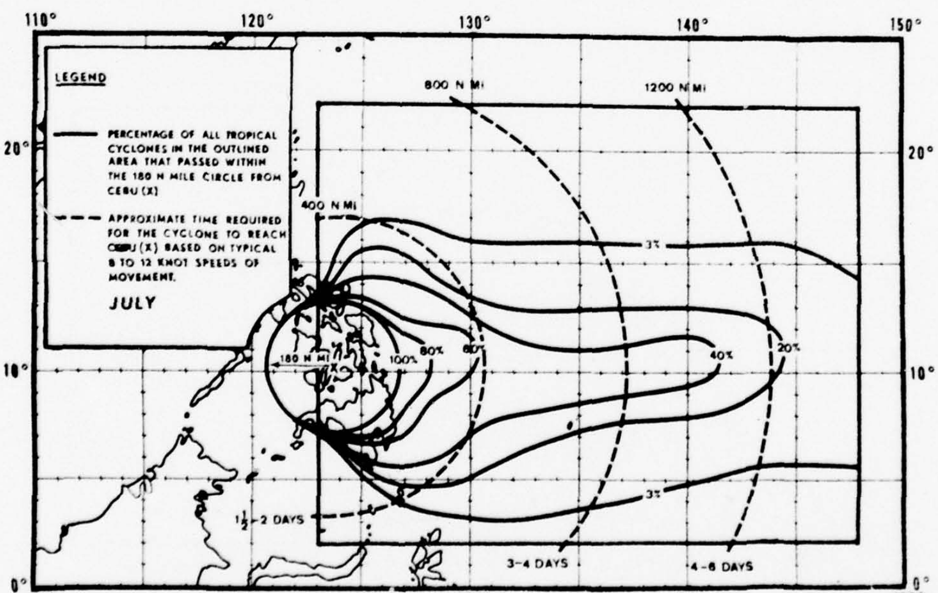

Figure VI-28. Probability that a tropical cyclone will pass within 180 n mi of Cebu (X) for the month of July (based on data from 1947-74).

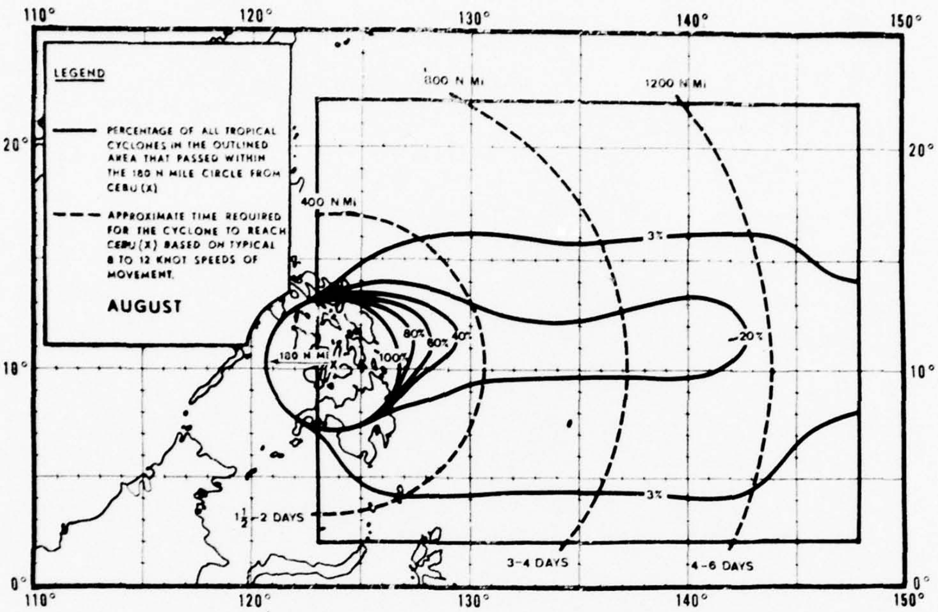

Figure VI-29. Probability that a tropical cyclone will pass within 180 n mi of Cebu (X) for the month of August (based on data from 1947-74).

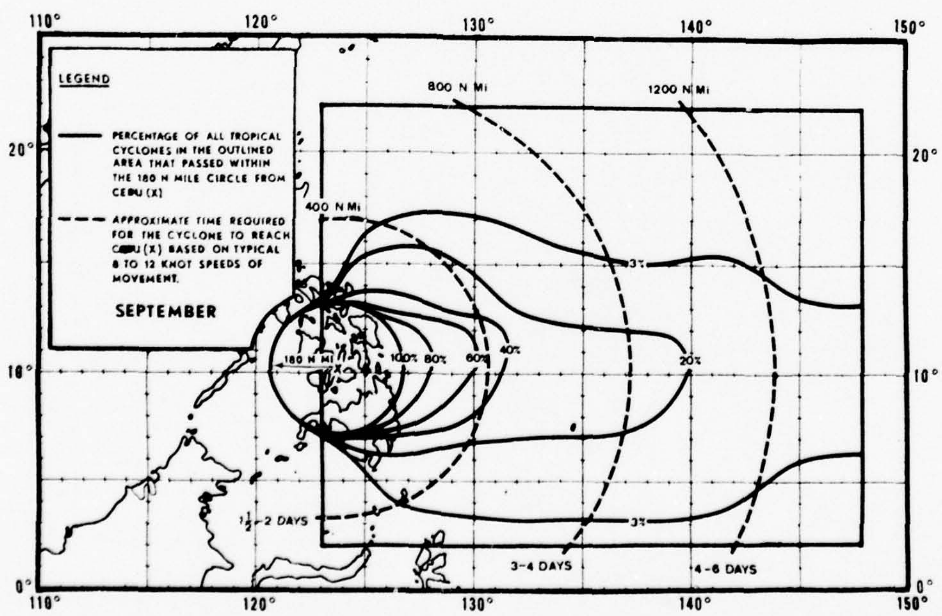

Figure VI-30. Probability that a tropical cyclone will pass within 180 n mi of Cebu (X) for the month of September (based on data from 1947-74).

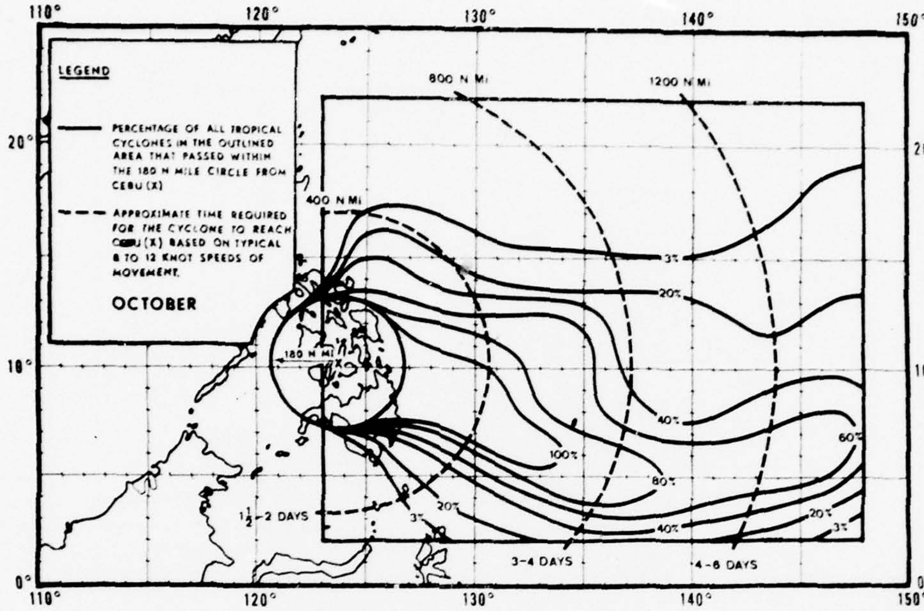

Figure VI-31. Probability that a tropical cyclone will pass within 180 n mi of Cebu (X) for the month of October (based on data from 1947-74).

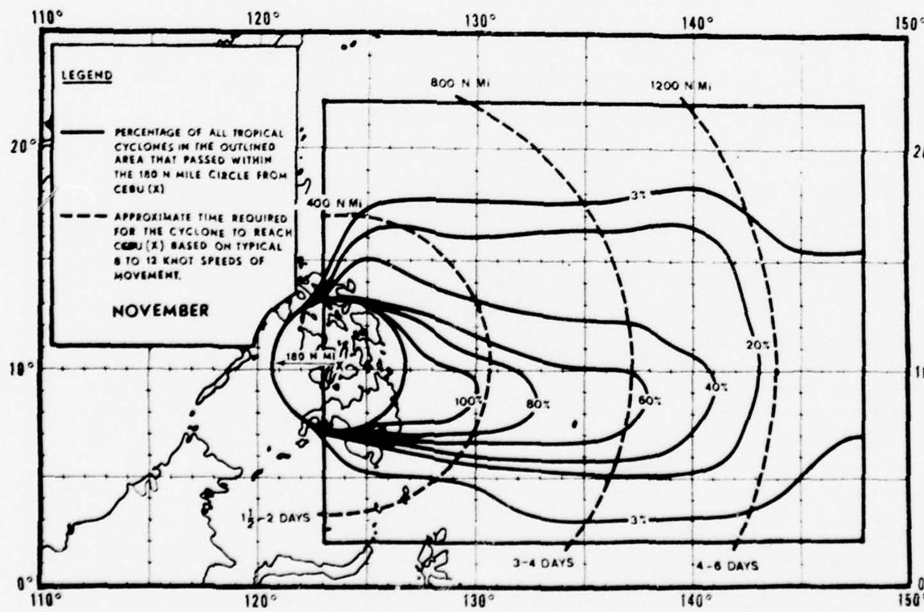

Figure VI-32. Probability that a tropical cyclone will pass within 180 n mi of Cebu (X) for the month of November (based on data from 1947-74).

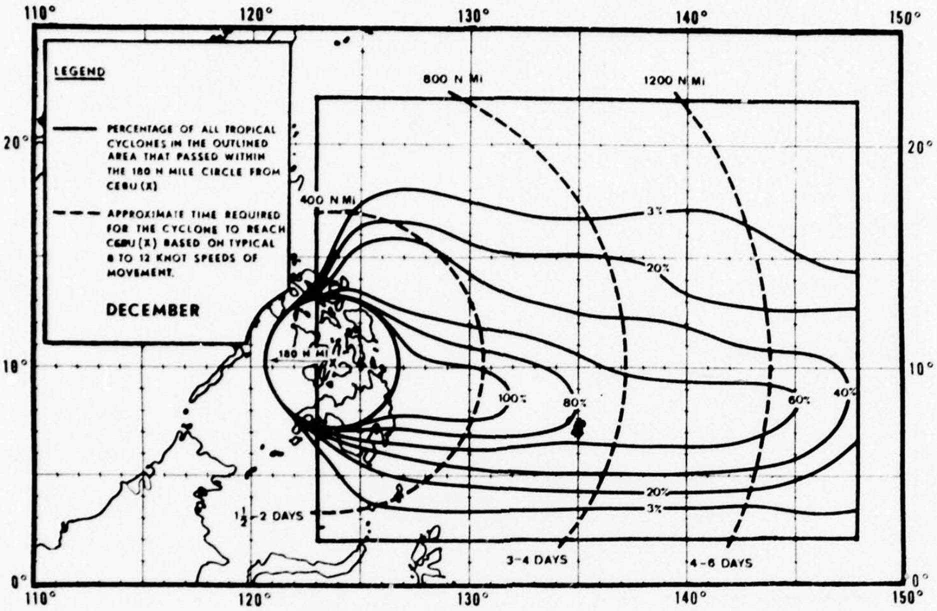

Figure VI-33. Probability that a tropical cyclone will pass within 180 n mi of Cebu (X) for the month of December (based on data from 1947-74).

5.5.2 Wind And Topographical Effects

In the 20-year period 1955-74, during the months June-December, a total of 45 tropical cyclones approached within 180 n mi of Cebu, which is more than two tropical cyclones per year. Approximately 82% of this sample had their closest point of approach (CPA) to the north of Cebu, while 18% passed to the south. The largest number of tropical cyclones to threaten Cebu in any single year was five in both 1971 and 1972. Table VI-3 groups these 45 tropical cyclones according to the wind intensity they produced at Cebu.

Table VI-3. Extent to which tropical cyclones affected Cebu during the period June-December, 1955-74, based on hourly wind data.

Number of tropical cyclones that passed within 180 n mi of Cebu	45
Number of tropical cyclones resulting in strong ($\geq$ 22 kt) winds at Cebu	6
Number of tropical cyclones resulting in gale force ($\geq$ 34 kt) winds at Cebu	3

Of the 45 tropical cyclones noted in Table VI-3, 13% resulted in strong winds ($\geq$ 22 kt) and only 7% resulted in gale force winds ($\geq$ 34 kt). These results are based on hourly wind data and are considered representative of the winds in Cebu Harbor in most situations. (Note that these wind data are reduced from hourly wind observations.) Although records of winds greater than 33 kt were noted on only three occasions during the 1955-74 period, several instances of significantly higher winds which occurred between reporting times were observed. An example of this occurrence was a recording of 50 kt gusts at Cebu City Airport with the passage of Typhoon Lucy in November 1962. For records available at Cebu City Airport weather station from 1949, the highest official recording for all times was a sustained wind of 85 kt as a result of Typhoon Amy at 0030 local time on 10 December 1951.

In Figure VI-34 the arrows showing tropical cyclone movement give the positions of tropical cyclone centers when winds first and last exceeded 21 kt at Cebu. Figure VI-35 shows the position of tropical cyclone centers when winds first and last exceeded 33 kt. In all instances, the onset of 22 kt winds did not occur until the tropical cyclones had advanced well into the Philippines (west of 125° east longitude) and were within 100 n mi of Cebu.

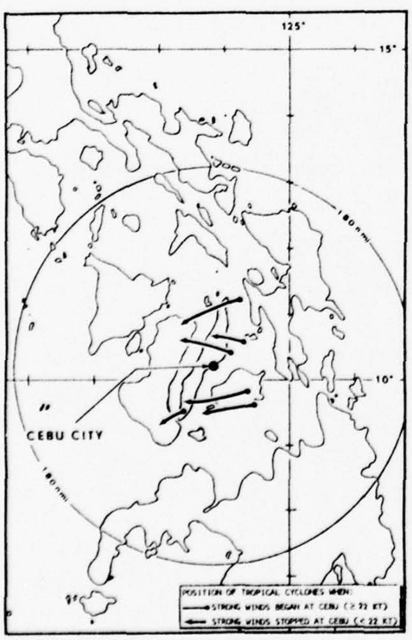

Figure VI-34. Positions of tropical cyclone centers when winds greater than or equal to 22 kt first and last occurred at Cebu (based on data from June-December 1955-74).

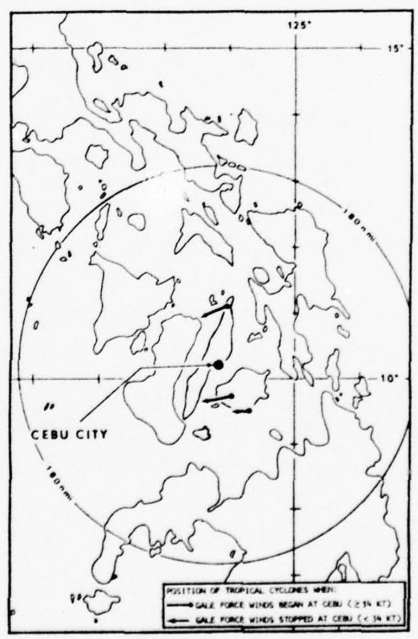

Figure VI-35. Positions of tropical cyclone centers when winds greater than or equal to 34 kt first and last occurred at Cebu (based on data from June-December 1955-74).

CEBU

A study of the 1955-74 period also revealed that strong winds as a result of a close tropical cyclone passage were generally restricted to winds from a sector northeast clockwise to the south-southwest. Tropical cyclones that have managed to approach close enough to severely effect Cebu City (i.e., sustained winds or gusts over 50 kt) have had close passage (within 50 n mi) equally to the north and south. However, the sample of occurrences is much too small to draw definitive conclusions as to the most severe threat to Cebu City in terms of direction of passage.

For a more detailed discussion on the effects of tropical cyclones in Cebu, see Hassell, 1976.

5.5.3 Wave Action

Maximum wave action is associated with a typhoon passing to the south or west since this places Cebu Harbor in the right or "dangerous" semicircle of the typhoon. The greater relative wind in this area generates waves which tend to be more destructive. The interior of Cebu Harbor is relatively well protected by the geography of the area, the southwest orientation of the bay and the nearby hydrography. Any waves that actually enter the bay must be as a result of refraction around islands surrounding Cebu from all directions, and are of little significance. Although there is no direct evidence, indications are that just outside the entrance to the harbor, maximum heights of approximately 6.5 ft can be obtained with winds of 50 kt and about 8 ft can be obtained with typhoon intensity ($\geq$ 64 kt) winds.

5.5.4 Storm Surge And Tides

Conversations with harbor authorities in Cebu City revealed no evidence of significant storm surge within the harbor of Cebu. Tidal currents in the harbor are reported variable and generally weak. However, conversations with harbor officials revealed normal tidal currents of 3 to a high of 7 kt that can attain values greater than 7 kt as a result of a close typhoon passage. Due to restricted maneuvering room in the harbor, U.S. ships would find maneuvering difficult if not impractical during the stronger tides resulting from a close passage of a typhoon. In addition, maneuvering within the inner harbor is restricted during normal ebb tide.

5.6 THE DECISION TO EVADE OR REMAIN IN PORT

5.6.1 Remaining In Port

Remaining in port when the means to evade a storm are available is a decision that is contrary to most of the traditional rules of seamanship. However, if the decision to remain in port is made, it should not be made without considering every available fact concerning the impending storm and the port in which the vessel is berthed. In the case of Cebu City the following points should be noted:

(1) Securing to a pier in the inner harbor is not recommended inasmuch as maneuvering is restricted during normal ebb tide, with winds greater than approximately 12 kt, and during tides greater than 7 kt (associated with tropical cyclones). (Only piers 1 and 2 are used for ocean-going vessels and use of these by USN vessels is recommended only for emergency measures.)

(2) Anchoring (south anchorage) should be completed prior to the onset of 20 kt winds as maneuvering is severely restricted.

(3) Once the decision to remain in port has been made, any reversal in plans would be extremely dangerous. Cebu City is a relatively sheltered harbor, so any wave and wind actions experienced inside the bay would be much more severe outside the entrance to the bay and in the open sea.

(4) Evasion from the harbor can only be accomplished via the southwest exit.

(5) The holding action of the mud bottom is considered by harbor officials to be minimal for typhoon conditions and there is danger of breaking loose in heavy weather.

(6) There is danger of other ships breaking loose.

5.6.2 Evasion

Evasion is the recommended course of action when threatened by a tropical cyclone. When evasion is contemplated, the importance of correctly assessing the threat posed by the storm and acting quickly so as to retain flexibility cannot be overemphasized. The following time table in conjunction with Figure VI-36 has been constructed for this purpose:

1. There is an existing tropical cyclone, or potential development in Area C, with forecast movement toward Cebu City:

   a. Review the material condition of the ship; sailing within 2-4 days is a distinct possibility.

   b. Reconsider all maintenance activities scheduled to exceed 48 hours.

2. A tropical cyclone has entered Area B with forecast movement toward Cebu City:

   a. Operational plans should be made in the event sortie is ordered.

   b. Reconsider all maintenance activities scheduled to exceed 24 hours.

3. A tropical cyclone has entered Area A with forecast movement toward Cebu City:

   a. Execute evasion plans made in previous steps.

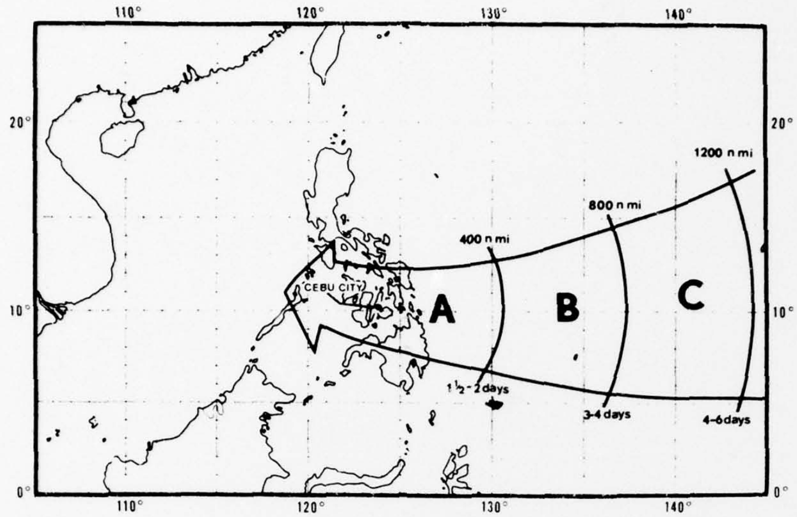

Figure VI-36. Tropical cyclone threat axis for Cebu City. Distances and approach times are measured from Cebu City based on an 8-12 kt speed of movement.

Whatever evasion decision is made, the following general comments should be considered.

(1) When departing Cebu City, ample time should be given to combat the heavy sea condition likely to be encountered at the entrance to the harbor.

(2) Crossing ahead of a typhoon should be accomplished well in advance. Heavy swells may be encountered ahead of an advancing typhoon long before the occurrence of strong winds. Such swells may decrease a ship's maneuverability and speed of advance, preventing avoidance of the typhoon track (see Para. 5, Chapter I).

(3) At certain times of the year, particularly in the peak typhoon season, the possibility exists that two or more tropical storms will be present at one time. This will greatly complicate any evasion planning and execution.

(4) A looping tropical cyclone can cause a false sense of security as evading ships attempt to return. A looping storm after initial passage can regenerate and cause as high or higher winds/seas upon its return.

5.6.3 Evasion Techniques

The final decisions involving evasion of tropical cyclones rest with the commanding officer of the vessel involved. One of the more successful Pacific Ocean evasion tactics involves running downwind and downsea relative to the typhoon in order to reach a latitude south of the storm and in the navigable semicircle. The success of this method depends upon almost continuous reconnaissance coverage, with the relatively slow movement and gradual expansion of the initially small area affected by severe winds which is characteristic of typhoons at low latitudes.

Due to the confined nature of the harbor (the restriction to use the southwest exit only) and the difficulty experienced in maneuvering a ship in strong winds, the ship should be ready to get underway before the storm approaches within 400 n mi (see Figure VI-36). If this general rule is followed, there will be more than ample time to clear restricted waters and evade before adverse weather can affect the sortie route.

For a ship in or near Cebu City, evasion to the southwest is a particularly sound tactic due to the harbor's close proximity to the equator. Typhoons rarely pass to the south of Cebu below 10°N and have never passed below 5°N (refer to Appendix I-A).

The following evasion techniques for the more common threat situations (any tropical cyclone expected to have a CPA within 180 n mi) are suggested:

1. Tropical cyclone forecast to pass north of Cebu City:

   a. Evasion should be to the southwest since units are already in the navigable semicircle and will remain there.

2. Tropical cyclone forecast to pass east of Cebu City:

   a. Evasion should be to the southwest since an eastward passing tropical cyclone may have already started recurvature and a westward heading will keep the ship in the navigable semicircle.

3. Tropical cyclone forecast to pass south of Cebu City:

   a. Evasion should be to the southwest. This decision should be made as early as possible in order to avoid meeting the storm.

It should be noted that some tropical cyclones do generate in the South China Sea each year. However, their normal tracks are to the west and/or north and no case of threat to the Cebu City area was noted in this study (refer to Appendix I-A).

In all cases, careful monitoring of the storm should be conducted to permit the utilization of the proper evasion technique in the event of a sudden change in storm track.

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REFERENCES

INSTRUCTIONS AND NOTICES

Commander, U.S. Seventh Fleet
COMSEVENTHFLT OPORD 201 (YR) Annex H

Commander, U.S. Navy Philippines
COMNAVPHILINST 3140.2

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SECTION VII - CONTENTS

VII KOREA

1. GENERAL

Figure VII-1 shows the geographical location and topography of the Korean Peninsula in the western North Pacific Ocean. To the north, Korea is bounded by Manchuria, and to the extreme northeast by Soviet Siberia. Since almost one-third of the tropical cyclones affecting Inchon travel across the eastern coastal areas of China, and over 40% of the tropical cyclones affecting Pusan/Chinhae traverse southwestern Japan, the topography of the respective regions has also been included in Figure VII-1.

Since 1945 the Korean Peninsula has been divided into two states, the Republic of Korea (ROK) in the south and the Democratic People's Republic of Korea in the north. They are separated by a demilitarized zone along the armistice line of 1954.

Mountains ranging between 3000-6000 ft are found in the central and eastern portions of the Peninsula's tip. Along the eastern shore of the Korean Peninsula a 3000-6000 ft range extends north to the Manchurian border where two mountain ranges extend up to 9000 ft.

A detailed study of the coast and harbors of Korea is included in H. O. Pub. 157, Sailing Directions (Enroute) for the Coasts of Korea and China.

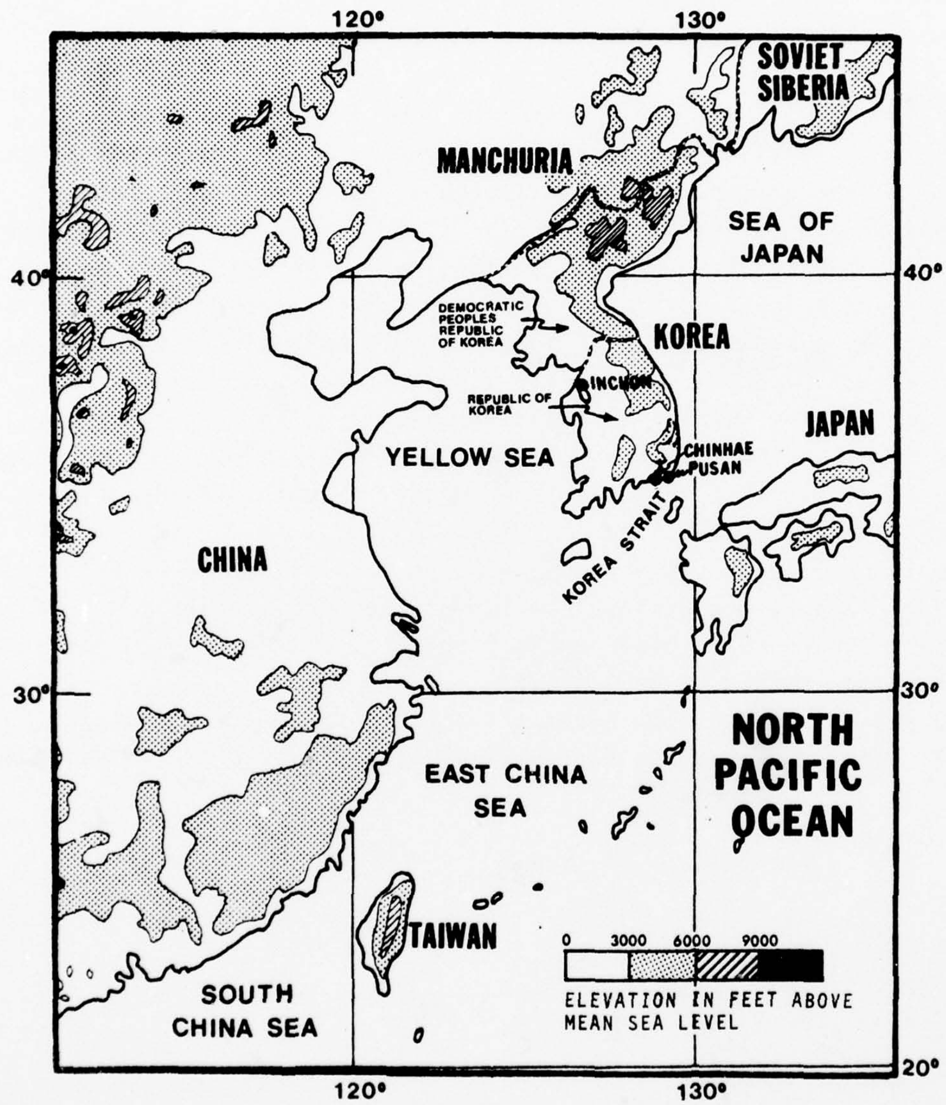

Figure VII-1. Locator map of the western North Pacific Ocean showing the positions and topographies of major land masses.

2. INCHON

SUMMARY

Inchon Harbor is a typhoon haven only if a ship is berthed in the tidal basin. If this is not possible, evasion to the Yellow Sea is recommended. Most of the tropical cyclones affecting Inchon are in the dissipating stage with central winds ranging generally between 45-60 kt. A well prepared ship should be able to ride this storm out at sea if it is positioned in the navigable semicircle.

2.1 LOCATION

Figure VII-2 shows the location of the port of Inchon at 37°28'N, 126°37'E on the west coast of the Korean Peninsula. Approximately 16 n mi to the north-east is Seoul, the South Korean capital. The port of Inchon serves as commercial outlet and port of entry for Seoul and is one of the largest cities in Korea. Inchon is situated on the estuary of the Yom River, a subsidiary outlet of the 320 n mi long Han River, which flows past Seoul.

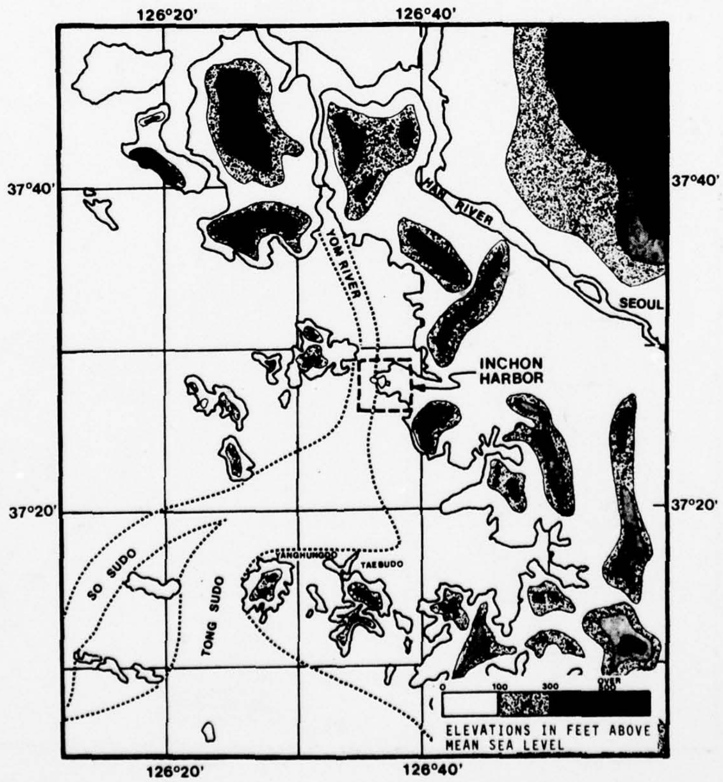

Figure VII-2. Mesoscale topography and geographic location of Inchon Harbor.

2.2 INCHON HARBOR

Inchon Harbor, one of Korea's principal deep water ports, consists of an outer harbor, an inner harbor for coastal vessels, and a tidal basin used by ocean-going vessels (see Figure VII-3).

The outer harbor consists of the Yom River area which provides numerous anchorages for deep draft vessels (see Figure VII-2). U.S. Navy ships are generally assigned anchorage E-3 or E-4. The holding action of the outer harbor bottom is best in the B anchorages while the A anchorages in the northern part of the harbor offer poor holding action in a rocky bottom. The large tidal range of 30 ft in conjunction with the strong currents which can exceed 3 kt make anchoring in the outer harbor inadvisable during a typhoon.

The inner harbor is used only by coastal vessels and is located south of So Wolmi Do (see Figure VII-3).

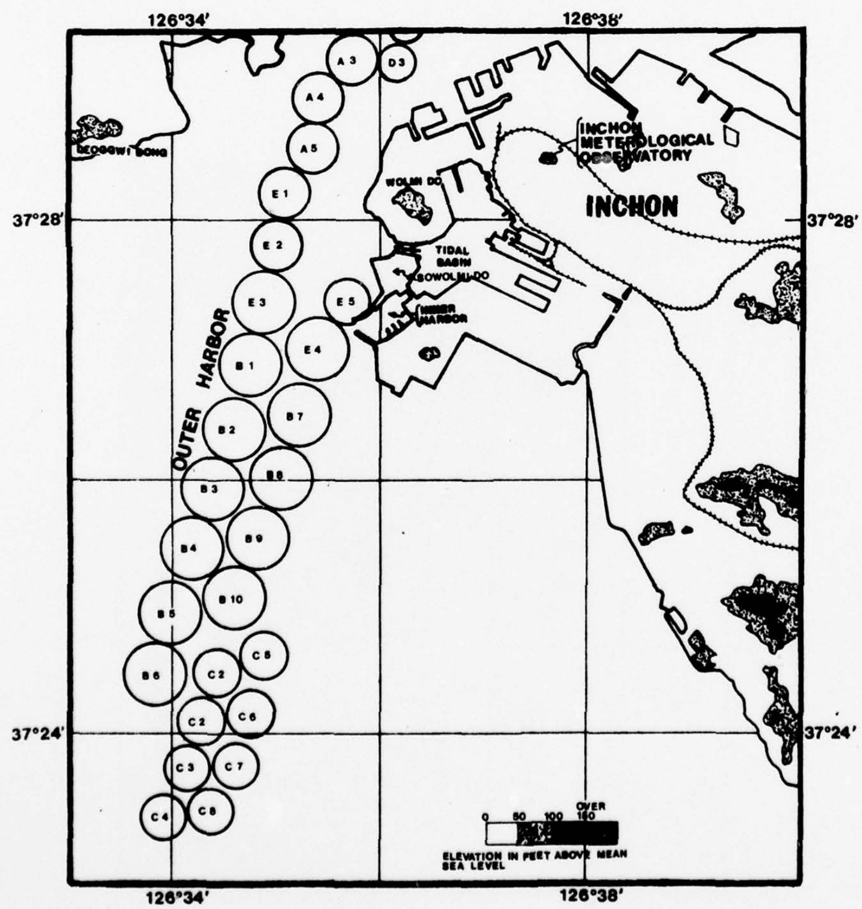

Figure VII-3. Inchon Harbor and local topography.

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The tidal basin is entered through either of two adjoining locks located between Wolmi Do and So Wolmi Do. The currents in the vicinity of the lock gate run perpendicular to the lock entrance; therefore, the tidal basin is entered only during slack tide. It takes approximately 1-1½ hours to clear the lock. Depths within the main part of the tidal basin vary between 4-5 fathoms, but there are certain areas where the water is considerably shallower.

Inchon Port is controlled and managed by the office of the Marine Bureau, Ministry of Transportation, ROK.

2.3 TOPOGRAPHY

Figure VII-2 indicates that Inchon Harbor is well protected by hills generally over 300-400 ft in all directions except to the southwest. The tidal basin receives further protection from the northwest by Wolmi Do with a height of 104 ft (see Figure VII-3).

2.4 HARBOR FACILITIES

For a detailed description of harbor facilities available in Inchon, the reader is referred to CINCPACFLT Port Directory or the Far East Port Directory.

2.5 TROPICAL CYCLONES AFFECTING INCHON

2.5.1 Tropical Cyclone Climatology for Inchon

For the purpose of this study, any tropical cyclone that approaches within 180 n mi of Inchon is considered to be a "threat" to the harbor and will be designated as a threat tropical cyclone.

Figure VII-4 gives the monthly summary by five-day periods of the threat tropical cyclones during June-October, 1947-73. In this 27-year period 36 threat tropical cyclones occurred, an average of 1.3 per year. Figure VII-4 also indicates that the tropical cyclone season for Inchon extends from the end of June to the beginning of October.

Most of the threat tropical cyclones affect Inchon after they have passed the recurvature point. (This means that the threat tropical cyclone's direction of motion at the closest point of approach (CPA) to Inchon had a northeasterly component of motion.) This is indicated in Figure VII-4 by the shaded area.

Figure VII-5 displays the threat tropical cyclones according to the compass octant from which they approached the 180 n mi radius threat area. It is evident that the majority of tropical cyclones (58%) entered the threat area from a sector extending from S to SW.

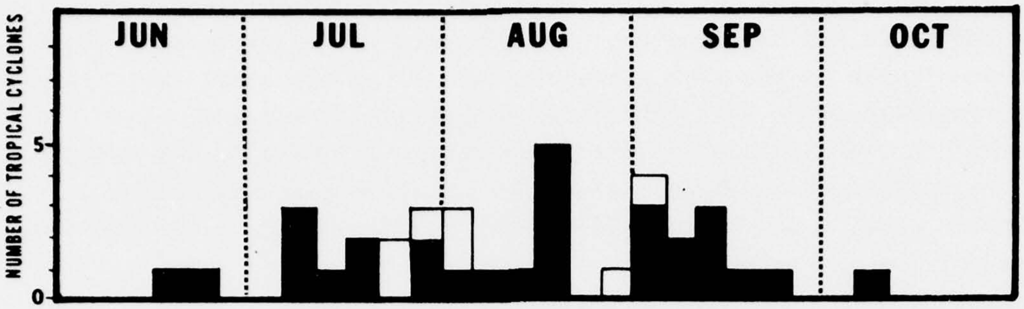

Figure VII-4. Frequency distribution of the number of tropical cyclones that passed within 180 n mi of Inchon. Subtotals are based on five-day periods for tropical cyclones that occurred during 1947-73. Shaded areas indicate the number of recurving tropical cyclones per five-day period.

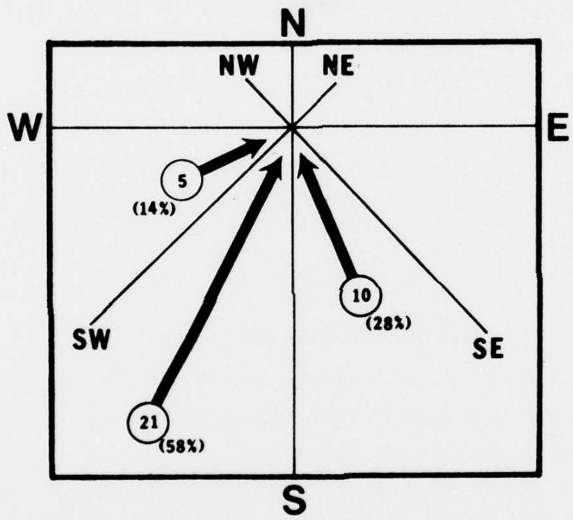

Figure VII-5. Directions from which tropical cyclones entered threat area (180 n mi radius circle centered at Inchon) during the period June-October 1947-73. Circled numbers indicate the number of tropical cyclones that entered from each octant. This is expressed as a percentage in ( ).

Of the 36 threat tropical cyclones during June-October 1947-73, 58% passed to the east of Inchon while 42% passed to the west. Therefore, the chance of an approaching threat tropical cyclone's passing to the east of Inchon is slightly greater than a passage to the west.

Approximately one-third of these threat tropical cyclones threatened Inchon after recurving over mainland China. This travel over land leaves a storm without the contact with a warm sea that is necessary for maintaining strong winds; in addition, the frictional effect of land further reduces the strong winds and the tropical cyclone weakens rapidly. When the tropical cyclone enters the Yellow Sea, it may intensify again given the proper sea surface temperature (SST) regime. The only months that have warm enough SST

values in the Yellow Sea are July-September. In general, the wind intensity of tropical cyclones that enter the Yellow Sea from mainland China increase on an average of 20%.

Figures VII-6 to VII-10 are based on an analysis of threat tropical cyclones during June-October, 1947-73. The solid lines represent percentage isolines of threat. The dashed lines represent approximate approach times to Inchon, computed from average tropical cyclone speeds of movement for June-October tropical cyclones affecting Inchon.

Figures VII-6 to VII-10 should prove useful in determining the probability of a tropical cyclone threatening Inchon from a given position within the grid. For example, a tropical cyclone located at 24N, 130E in June (see Figure VII-6) will have a 20% probability of passing within 180 n mi of Inchon, and it could reach Inchon in less than three days.[1]

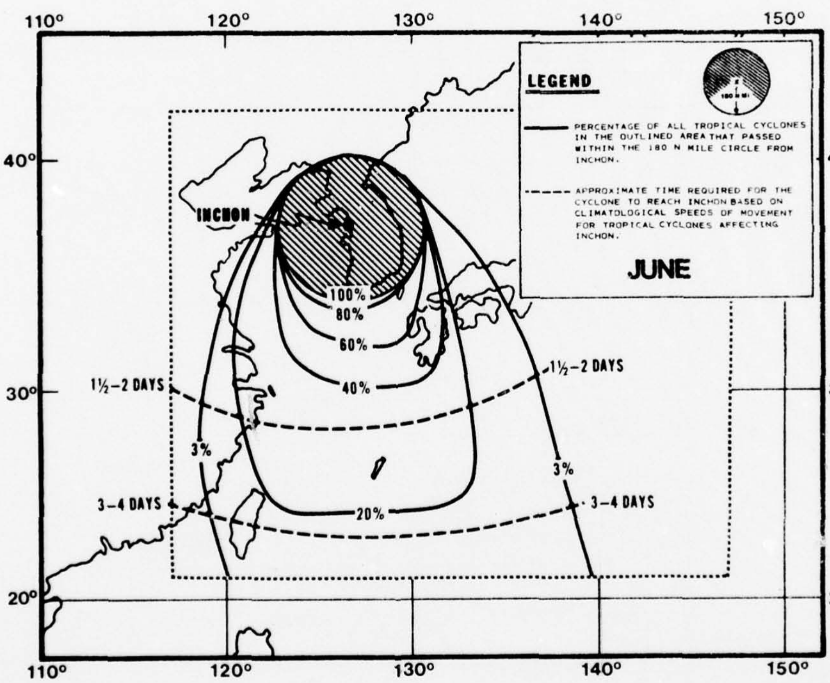

Figure VII-6. Probability that a tropical cyclone will pass within 180 n mi of Inchon for the month of June (based on data for June-October, 1947-73).

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[1]Caution should be used when considering Figures VII-6 (June) and VII-10 (October), since a limited number of occurrences provided information for these figures.

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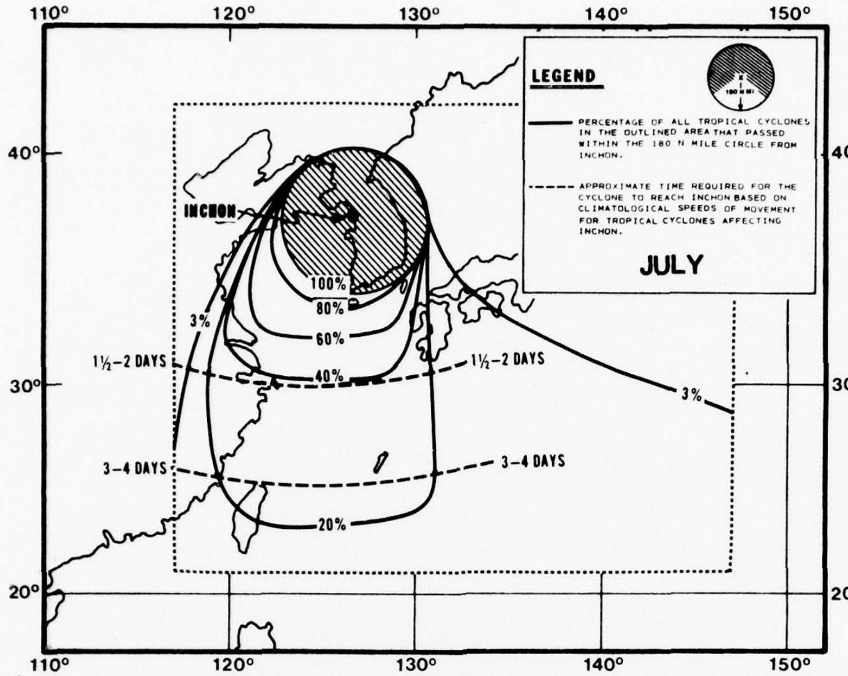

Figure VII-7. Probability that a tropical cyclone will pass within 180 n mi of Inchon for the month of July (based on data for June-October, 1947-73).

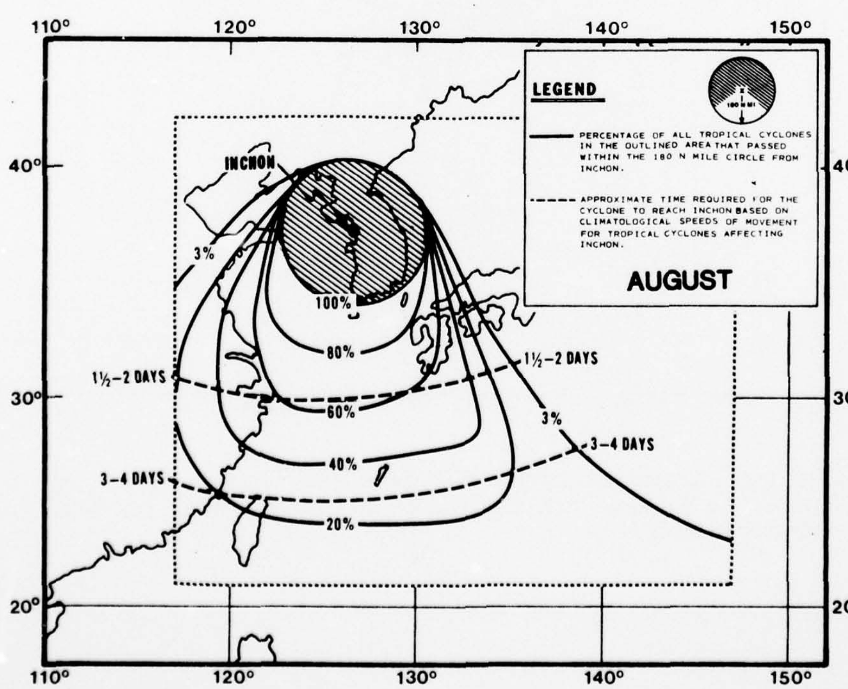

Figure VII-8. Probability that a tropical cyclone will pass within 180 n mi of Inchon for the month of August (based on data for June-October, 1947-73).

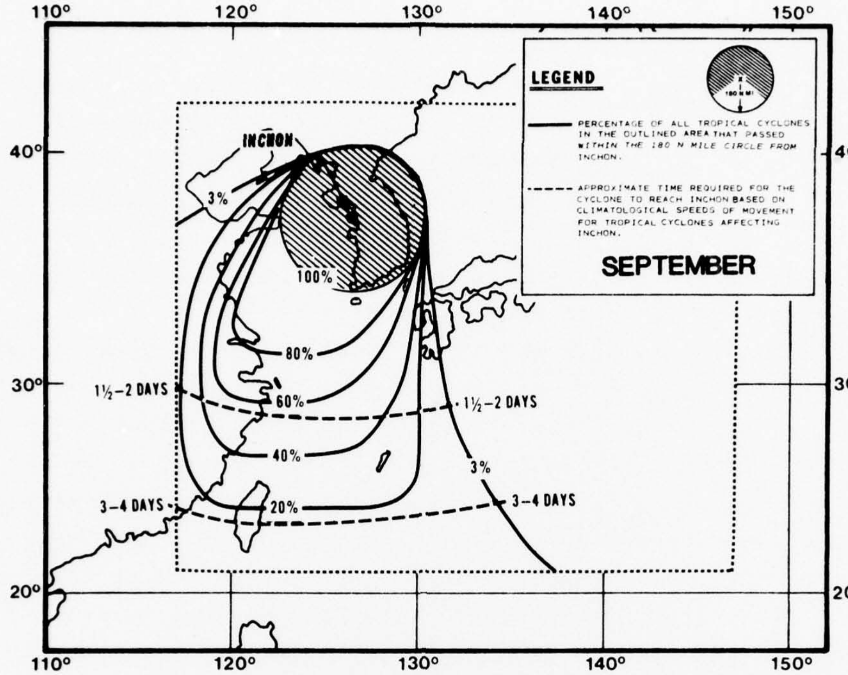

Figure VII-9. Probability that a tropical cyclone will pass within 180 n mi of Inchon for the month of September (based on data for June-October, 1947-73).

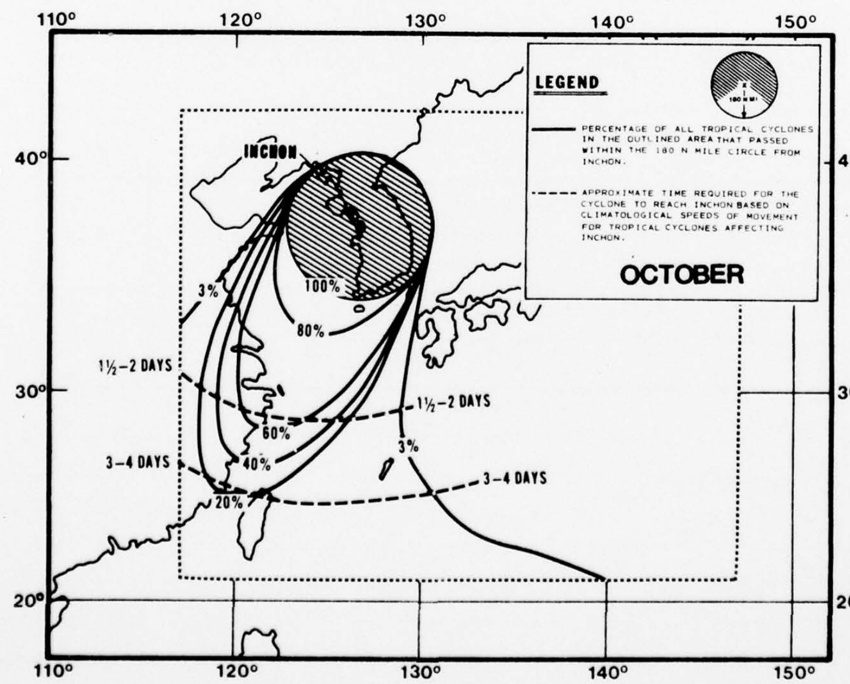

Figure VII-10. Probability that a tropical cyclone will pass within 180 n mi of Inchon for the month of October (based on data for June-October, 1947-73).

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2.5.2 Wind and Topographical Effects

From analyses of threat tropical cyclone tracks it is apparent that tropical cyclones producing gale force winds ($\geq$ 34 kt) at Inchon can pass either to the east or west. If the tropical cyclone path is to the east of Inchon, some of its intensity will be lost through interaction with the land. Tropical cyclone passage to the east will also produce northerly winds at Inchon as a result of the storm's counterclockwise rotation. The land masses to the north and northeast will provide protection from the winds.

Wind observations from the Inchon Meteorological Observatory were analyzed to determine the extent to which threat tropical cyclones produced strong winds ($\geq$ 22 kt) or gale force winds ($\geq$ 34 kt) at Inchon. The Observatory (37°28'31"N, 126°37'38"E, see Figure VII-3) is located atop a 267-ft hill and since this is the highest peak in Inchon proper, winds recorded here are representative of wind conditions existing in the harbor. The hourly wind observations from this recording site were analyzed for the period June-October, 1952-73. Table VII-1 groups the 31 tropical cyclones that threatened Inchon during this 22-year period according to the wind intensities they produced at Inchon. Only 24% of the threat tropical cyclones produced gale force ($\geq$ 34 kt) winds at Inchon. It should be noted that the maximum sustained wind ever observed during this period was less than 50 kt.

Table VII-1. Extent to which threat tropical cyclones affected Inchon during June-October, 1952-73.

Number of tropical cyclones that threatened Inchon	31	--
Number of threat tropical cyclones resulting in strong ($\geq$ 22 kt) winds in Inchon	14	42%
Number of threat tropical cyclones resulting in gale force ($\geq$ 34 kt) winds in Inchon	8	24%

Figure VII-11 shows the positions of threat tropical cyclone centers when strong winds ($\geq$ 22 kt) were first and last recorded at the Inchon Meteorological Observatory. It is apparent that threat tropical cyclones generally produce winds $\geq$ 22 kt at Inchon when north of 35° latitude.

Figure VII-12 shows tropical cyclone center positions when gale force ($\geq$ 34 kt) winds were first and last recorded at the Inchon Meteorological Observatory. It can be seen that winds $\geq$ 34 kt generally do not begin until the storm is north of 37° latitude and that no threat tropical cyclones to the southeast of Inchon produced gale force winds.

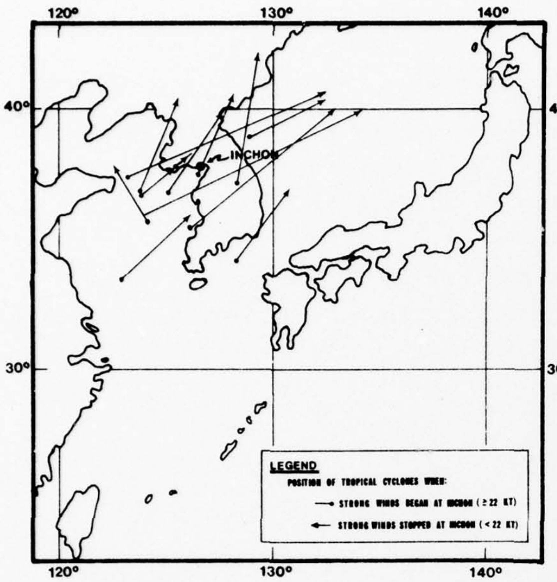

Figure VII-11. Positions of tropical cyclone centers when $\geq$ 22 kt winds first and last occurred at Inchon (based on data for June-October, 1952-73).

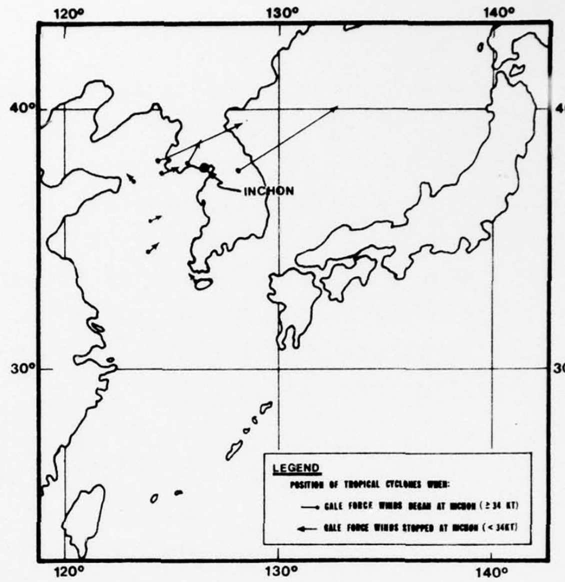

Figure VII-12. Positions of tropical cyclone centers when $\geq$ 34 kt winds first and last occurred at Inchon (based on data for June-October, 1952-73).

2.5.3 Wave Action

Maximum wave action is associated with a typhoon passing to the west since this places Inchon in the right or "dangerous" semicircle of the typhoon. The greater relative wind in this area generates waves which tend to be more destructive. The maximum wave heights that can be expected with typhoon strength winds ($\geq$ 64 kt) in Inchon Harbor are given in Table VII-2.

Table VI-2. Maximum wave heights that can be expected with typhoon strength winds ($\geq$ 64 kt) in the outer harbor (northern and southern part) and tidal basin of Inchon.

Location	Outer Harbor		Tidal Basin
	Northern Part	Southern Part	
Winds generally from the north (tropical cyclone passage east of Inchon)	5 ft	6 ft	4 ft
Winds generally from the south (tropical cyclone passage west of Inchon)	8 ft	7 ft	4 ft

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2.5.4 Storm Surge and Tides

When a tropical cyclone crosses a coastline, a rise in water level may occur because of wind stress on the water surface and the effects of atmospheric pressure reduction. The height of the storm surge is dependent on the tropical cyclone track, so the peak surge will be large if the track is to the west of Inchon and small if the track is to the east.

The large tidal range of Inchon Harbor (30 ft) may make the surge effect seem negligible. However, if the tropical cyclone is forecast to pass to the west of Inchon and this coincides with high tide, an extremely large rise in water level can be anticipated.[2]

2.6 THE DECISION TO EVADE OR REMAIN IN PORT

2.6.1 Evasion

Evasion from Inchon Harbor is the recommended course of action if shelter in the tidal basin is not available. Remaining at anchor in the outer harbor is not recommended for the following reasons:

(1) The currents in the outer harbor may exceed 3 kt.

(2) The holding action of the outer harbor bottom is good only in the southern anchorages.

(3) At least one ship has run aground after dragging anchor in the northern part of the outer harbor.

During the 22-year period 1952-73, the maximum sustained wind reported in Inchon resulting from a tropical cyclone was less than 50 kt. This is partly due to the fact that most of the tropical cyclones affecting Inchon are dissipating in intensity (see Para. 3, Chapter I). Therefore, it is felt that the best evasion procedure is to head for the Yellow Sea and then maneuver in such a manner as to place the ship in the navigable semicircle. Since the waters near Inchon Harbor are restricted and the currents in the approach channels may be quite strong, especially in So Sudo Channel (see Figure VII-2) where current velocities up to 8 kt have been reported, evasion must commence early. Given a strong current, a ship steaming at 10 kt will require approximately 6 hr to clear the outer harbor and reach the open water of the Yellow Sea.

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[2] For a more detailed discussion on the effects of tropical cyclones on Inchon, refer to "An Evaluation of the Harbors of Inchon, Pusan and Chinhae, Republic of Korea as Typhoon Havens," by D. Rudolph, NAVENVPREDRSCHFAC Technical Paper No. 22-75, 1975.

Figure VII-13 shows the tropical cyclone threat axis for Inchon. The area enclosed within the arrow represents a 30% or greater probability of a tropical cyclone coming within 180 n mi (indicated by the hatched circle) of Inchon. To facilitate early evasion action, the following timetable has been established in conjunction with Figure VII-13:

I. An existing tropical cyclone moves into or development takes place in area A with forecast movement toward Korea:

  a. Review material condition of ship. A sortie may be desirable within 2 days.

  b. Reconsider any maintenance that would render the ship incapable of getting underway within 48 hours.

II. Tropical cyclone enters area B with forecast movement toward Inchon:

  a. Operational plans should be made in the event of a sortie.

  b. Reconsider any maintenance that would render the ship incapable of getting underway within 24 hours.

III. Tropical cyclone enters area C moving toward Inchon:

  a. Execute evasion plans made in previous steps.

An alternative evasion procedure used by the large vessels of the ROK Navy is to anchor just north of Taebu Do and Yanghung Do (see Figure VII-2). However, unfamiliarity with the waters in this vicinity and proximity to land masses may make this evasion technique unattractive to commanding officers.

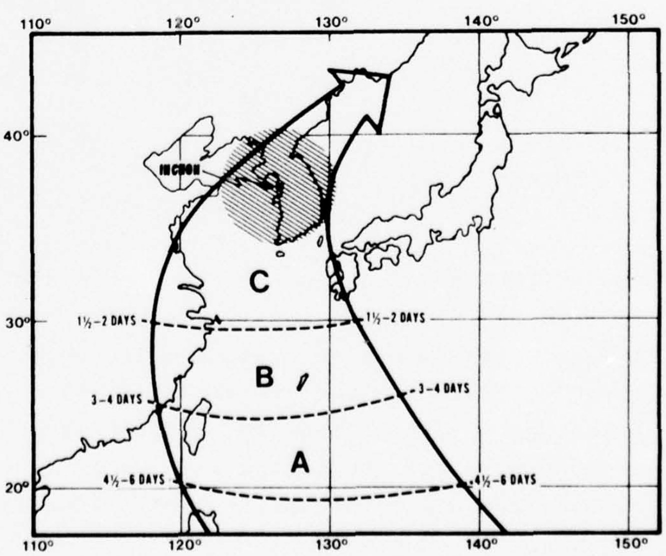

Figure VII-13. Tropical cyclone threat axis for Inchon. Approach times are based on average speeds of movement for tropical cyclones affecting the Inchon area.

2.6.2 Remaining In Port

Remaining in port at Inchon is recommended only if shelter is available in the tidal basin. If shelter is not available there, evasion is recommended. The tidal basin provides good protection from threat tropical cyclones for the following reasons:

(1) Good protection from strong winds is provided by the surrounding topography. The maximum sustained wind recorded at Inchon resulting from a tropical cyclone was less than 50 kt.

(2) The tidal basin provides excellent protection from high seas. The maximum wave height that can be expected is 4 ft.

To facilitate early action if it is decided to remain in port, the following timetable has been established in conjunction with Figure VII-13:

I. An existing tropical cyclone moves into or development takes place in area A with forecast movement toward Korea:

a. Review material conditions of ship. Movement to the tidal basin may be desirable in 2-4 days.

b. Reconsider any maintenance that would render the ship incapable of getting underway within 48 hours.

II. Tropical cyclone enters area B with forecast movement toward Inchon:

a. Determine if berth is available in tidal basin. Plans should be made for move to the tidal basin. Recall that tidal basin can only be entered at slack tide.

b. Reconsider any maintenance that would render the ship incapable of making the move to the tidal basin within 24 hours.

III. Tropical cyclone enters area C moving toward Inchon:

a. Execute plans for movement to the tidal basin.

The ROK Navy utilizes the B anchorages in the southern part of the outer harbor as typhoon anchorages for medium-size vessels such as DDG's, DD's, etc. The holding action of the harbor bottom is good here and there have been no reports of ships dragging anchor in this area. However, due to the strong currents (in excess of 3 kt) and the great tidal range, anchoring in the outer harbor should only be considered if there is no berth available in the tidal basin and it is too late to evade the tropical cyclone in the Yellow Sea. Under no circumstances should the anchorages in the northern part of the outer harbor be utilized during the passage of a tropical cyclone.

3. PUSAN

SUMMARY

It is the recommendation of this study that all U.S. Navy ships capable of taking action sortie from Pusan when threatening tropical cyclone conditions exist.

The preferred evasion technique is to evade the tropical cyclone in the Sea of Japan or, if need exists to remain in Korean waters, to seek shelter in Chinhae Bay.

3.1 LOCATION

Figure VII-14 shows the location of Pusan Harbor on the southeast coast of the Korean Peninsula at 35°06'N, 129°02'E.

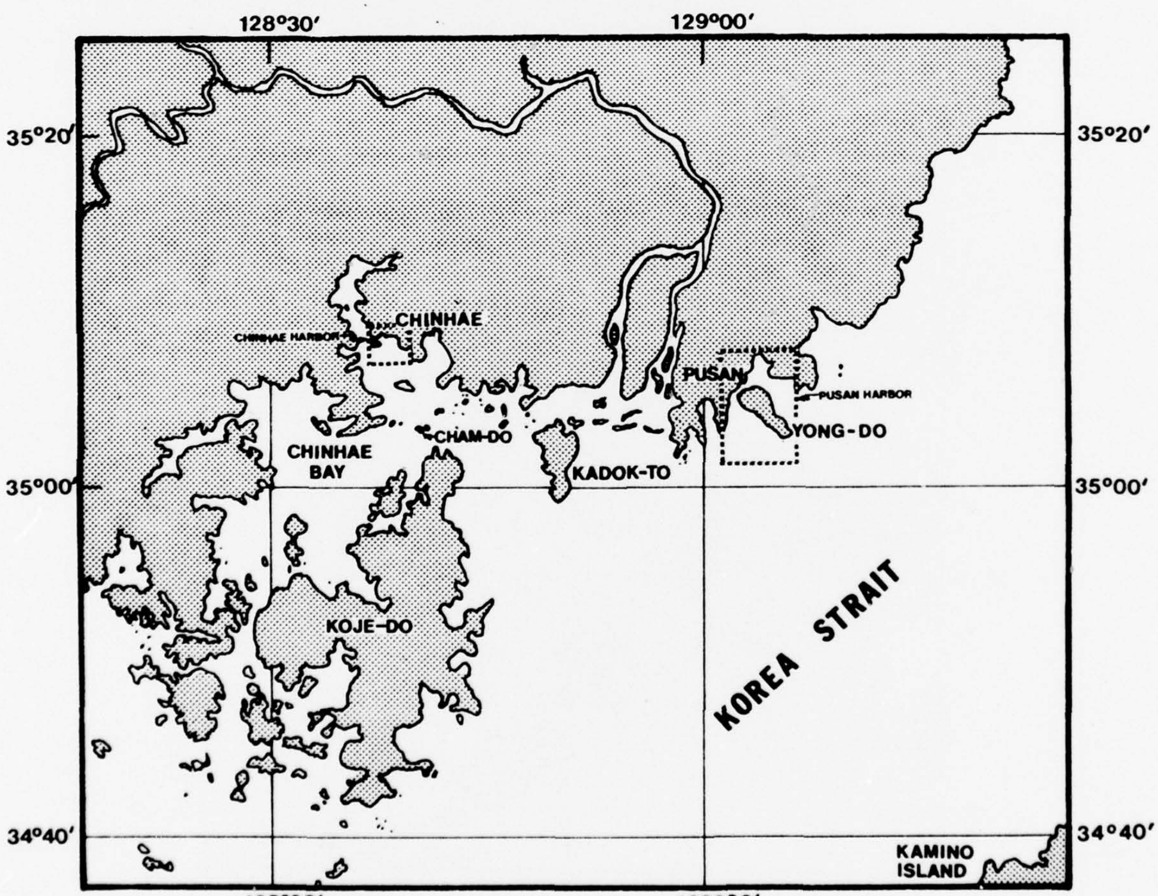

Figure VII-14. Locations of Pusan and Chinhae on the southeastern tip of the Korean Peninsula.

3.2 PUSAN HARBOR

Pusan Harbor, Korea's principal deep water port, is divided by Yong-Do Island into a northern and southern harbor (see Figure VII-15). Both harbors are further divided into inner and outer harbors. North Harbor accommodates ocean-going vessels while South Harbor is used primarily by coastal vessels. Unless otherwise stated, reference to Pusan Harbor will specifically apply to North Harbor. An intensive construction program is presently underway in the North Harbor. This includes dredging of the fairway and construction of container and grain piers. Anchorages are available in the outer and inner harbors. With the exception of a few rocky patches in the outer harbor, good anchor holding action is available in a mud and sand bottom. The inner harbor is one of the few in Korea where deep-draft vessels can berth at piers.

The range of tides in Pusan Harbor is approximately 4 ft. In the narrow channels between Yong-Do Island (see Figure VII-15) and Pusan Harbor, tidal currents attain velocities of 3-4 kt.

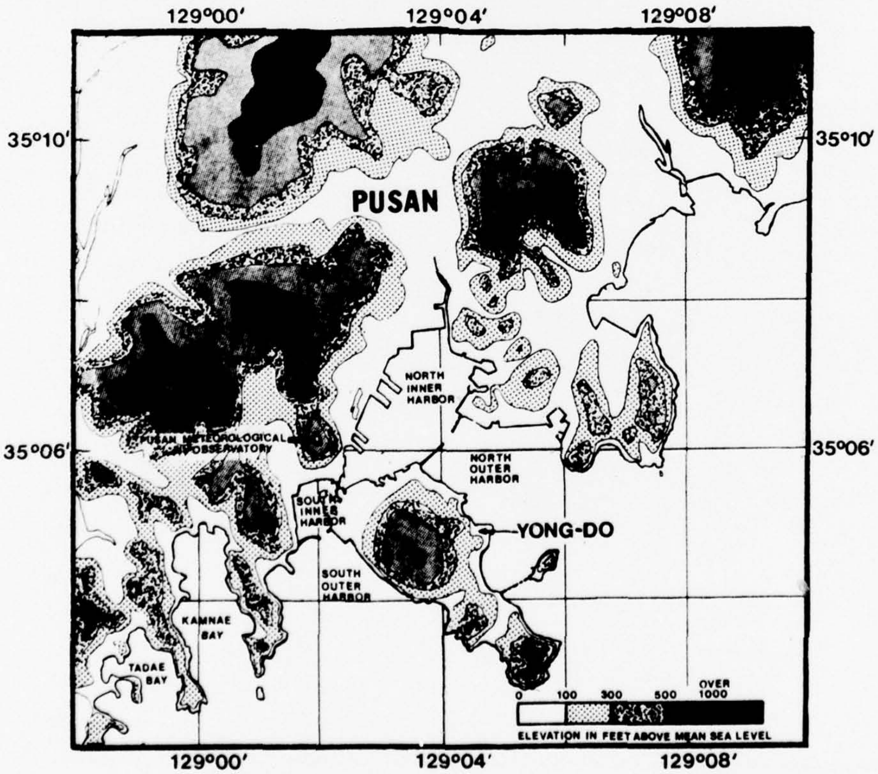

Figure VII-15. Pusan Harbor and surrounding topography.

3.3 TOPOGRAPHY

Pusan Harbor is well protected by hills in all directions except to the southeast and southwest where it faces the sea and to the north where the port opens into a valley (see Figure VII-15).

3.4 HARBOR FACILITIES

Pusan's inner harbor consists of four major piers, two quays, and six deep-draft anchorages. Cranes, drydocks and repair facilities are all available. For a detailed description of available harbor facilities, refer to CINCPACFLT Port Directory or to the Far East Port Directory.

3.5 TROPICAL CYCLONES AFFECTING PUSAN

3.5.1 Tropical Cyclone Climatology For Pusan And Chinhae Harbors

The climatology of tropical cyclones for Pusan and Chinhae Harbors will be combined since the two harbors are less than 20 n mi apart. The midpoint of a line between the two harbors was used to define this climatology. For purposes of this study, any tropical cyclone that entered a 180 n mi circle radially outward from this midpoint was considered to be a "threat" to Pusan/Chinhae Harbor and designated as a threat tropical cyclone.

The threat period for Pusan/Chinhae extends from the end of June through the middle of October. This is indicated in Figure VII-16 which depicts the monthly summary by five-day periods of tropical cyclone occurrences based on data for June-October, 1947-1973. During this 27-year period, 57 tropical cyclones threatened Pusan/Chinhae, an average of approximately two per year. August is the peak threat period, followed by September and July. Figure VII-16 also indicates that most of the threat tropical cyclones were "recurvers" (had a northeasterly component of motion).

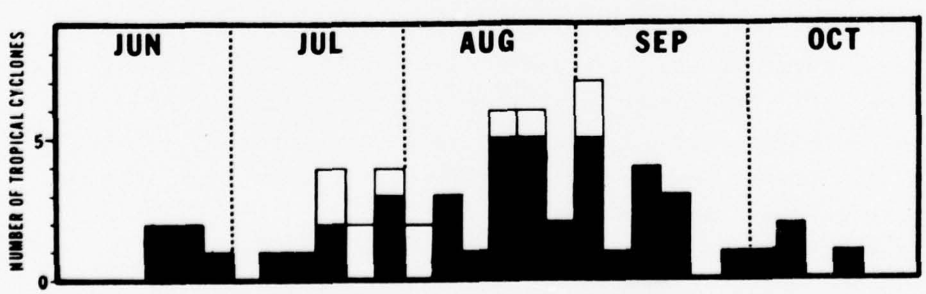

Figure VII-16. Frequency distribution of the number of tropical cyclones that passed within 180 n mi of Pusan/Chinhae. Subtotals are based on five-day periods for tropical cyclones that occurred during 1947-73. Shaded areas indicate the number of recurving tropical cyclones per five-day period.

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Figure VII-17 displays the threat tropical cyclones according to the compass octant from which they approached Pusan/Chinhae. It is evident that 81% of the threat tropical cyclones entered the threat area from a sector extending from SW to SE.

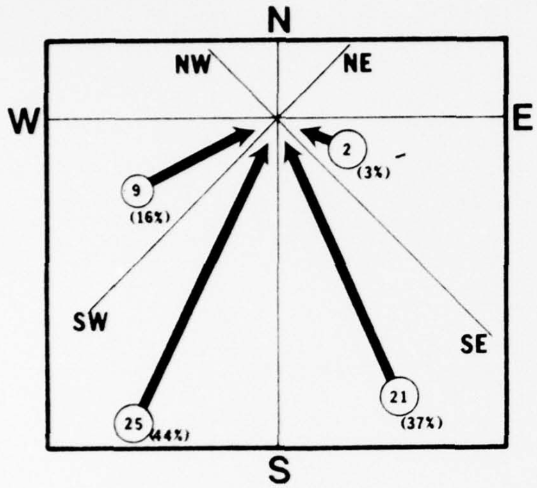

Figure VII-17. Directions of approach to Pusan/Chinhae of tropical cyclones that passed within 180 n mi of Pusan/Chinhae during the period 1947-73. Circled numbers indicate the number of tropical cyclones that approached from each octant. This is expressed as a percentage in ( ).

Of the 57 threat tropical cyclones during June-October, 1947-73, 54% passed to the west and 46% passed to the east of the midpoint of a line between Pusan and Chinhae. Therefore, the chances of having a threat tropical cyclone pass to the west of this midpoint are somewhat greater than passage to the east.

Over 40% of the threat tropical cyclones affecting Pusan/Chinhae either travel over or dissipate on the southwestern tip of Japan. As a result of a tropical cyclone's interaction with land, the maximum wind intensity decreases. *During August (including the end of July - beginning of September)* the mean sea surface temperatures (SST) in the Sea of Japan and Yellow Sea are favorable for a tropical cyclone's reintensification when it leaves the southwestern tip of Japan.

Figures VII-18-VII-22 are based on an analysis of threat tropical cyclones from June-October, 1947-73. The approach times (dashed lines) are based on the average speeds of movement of tropical cyclones that affect Pusan/Chinhae. The solid lines represent the "percent threat" for any storm location. For example, in Figure VII-18, a storm located at 30N and 130E has a 40% probability of passing within 180 n mi of Pusan/Chinhae and it could reach Pusan/Chinhae in less than one day.

Note the significant shift in direction from which threat tropical cyclones approach Pusan/Chinhae. In June, the approach is generally from the southwest, whereas in July it is from the southeast. During August the threat sector extends from south to southeast, and in September it extends from the southeast and southwest. During October the threat sector narrows again and is primarily from the south-southeast.

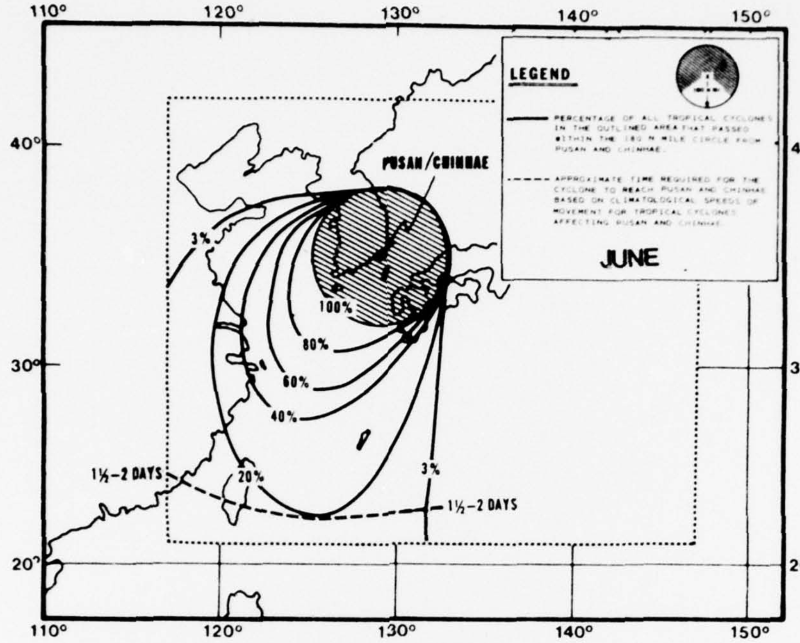

Figure VII-18. Probability that a tropical cyclone will pass within 180 n mi of the midpoint of a line between Pusan and Chinhae Harbors for the month of June (based on data for June-October, 1947-73).

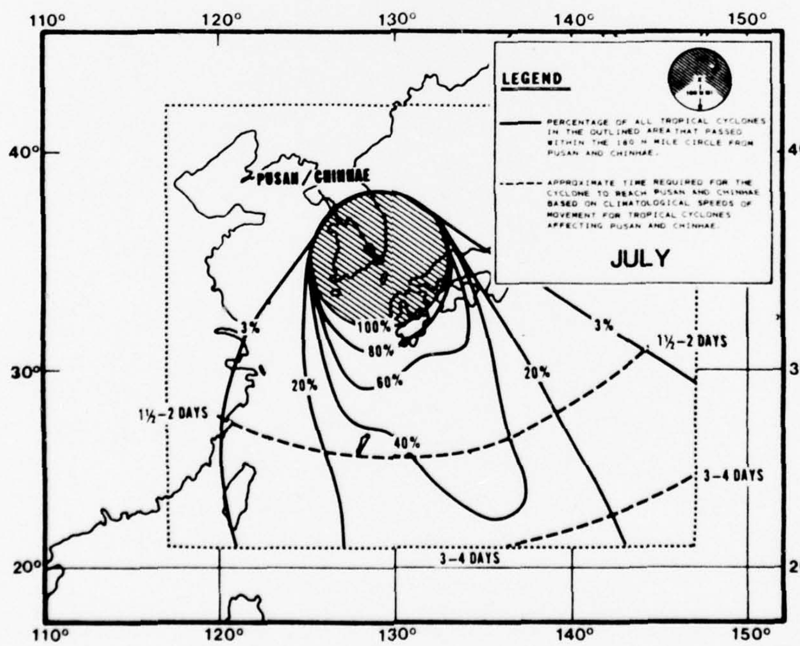

Figure VII-19. Probability that a tropical cyclone will pass within 180 n mi of the midpoint of a line between Pusan and Chinhae Harbors for the month of July (based on data for June-October, 1947-73).

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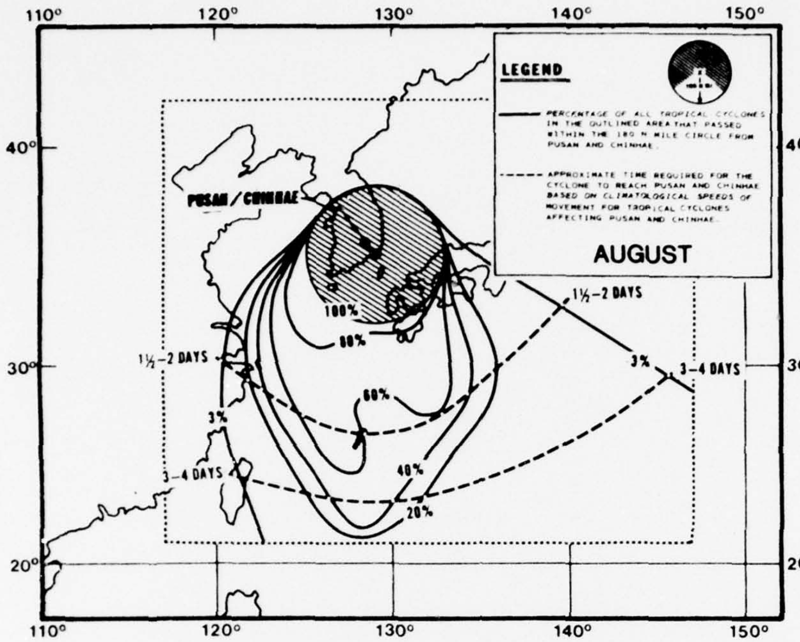

Figure VII-20. Probability that a tropical cyclone will pass within 180 n mi of the midpoint of a line between Pusan and Chinhae Harbors for the month of August (based on data for June-October, 1947-73).

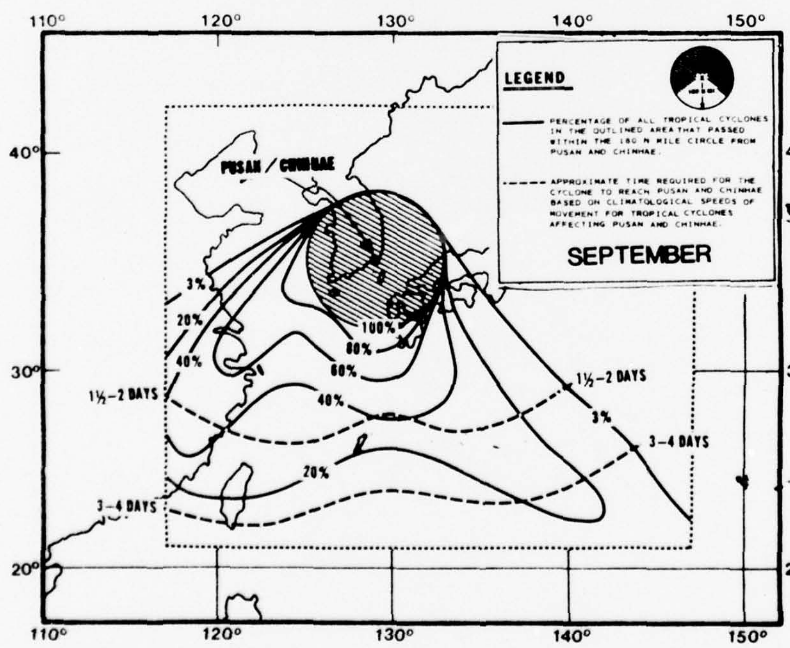

Figure VII-21. Probability that a tropical cyclone will pass within 180 n mi of the midpoint of a line between Pusan and Chinhae Harbors for the month of September (based on data for June-October, 1947-73).

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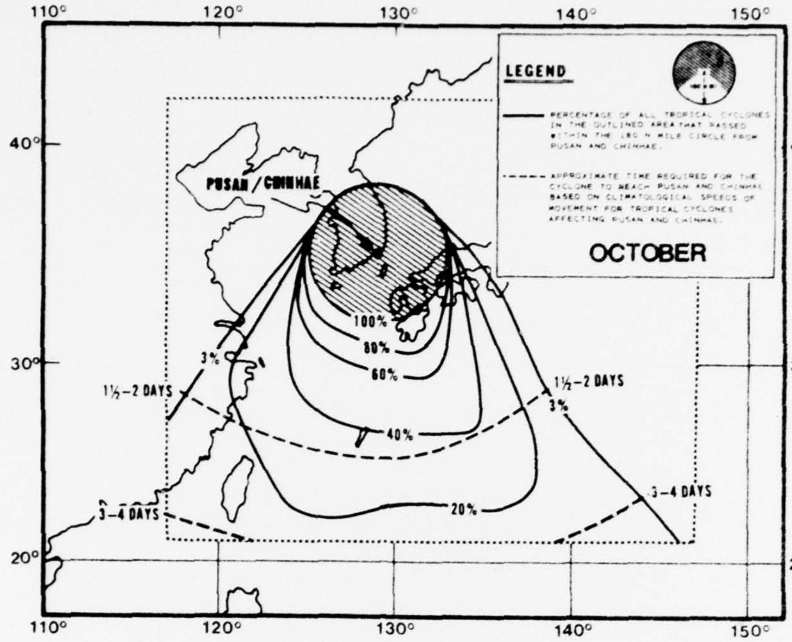

Figure VII-22. Probability that a tropical cyclone will pass within 180 n mi of the midpoint of a line between Pusan and Chinhae Harbors for the month of October (based on data for June-October, 1947-73).

3.5.2 Wind and Topographical Effects

Based on topographical considerations, strong winds can be expected from the north-northeast, southeast and southwest of Pusan since little topographic protection from these directions exists (see Figure VII-15). The southerly winds would be associated with threat tropical cyclone passage to the west of Pusan while northerly winds would result from passage to the east.

Wind observations from the Pusan Meteorological Observatory for June-October, 1948-73 were analyzed to determine the extent to which threat tropical cyclones produced strong winds ($\geq$ 22 kt) or gale force winds ($\geq$ 34 kt) at Pusan. The close proximity of the Observatory to the harbor (35°06'N, 129°02'E; see Figure VII-15) makes the winds recorded at the station generally representative of the wind conditions experienced in the harbor.

Table VII-3 groups the 55 tropical cyclones that threatened Pusan during this 26-year period according to the wind intensity that they produced at Pusan. Of these 55, 67% resulted in strong winds ($\geq$ 22 kt) and 29% resulted in gale force winds ($\geq$ 34 kt).

Table VII-3. Extent to which threat tropical cyclones affected Pusan during June-October, 1948-73.

Number of tropical cyclones that threatened Pusan	55	--
Number of threat tropical cyclones resulting in strong (≥ 22 kt) winds in Pusan	37	67%
Number of threat tropical cyclones resulting in gale force (≥ 34 kt) winds in Pusan	16	29%

The following are apparent from analyses of the threat tropical cyclone tracks:

(1) Gale force winds resulting from a threat tropical cyclone occurred in each month during June-October

(2) The threat tropical cyclones producing gale force winds at Pusan are more likely to pass to the west of Pusan (62%) than to the east (38%)

Figure VII-23 shows the positions of threat tropical cyclone centers when strong winds (≥ 22 kt) were first and last recorded at Pusan. It is obvious that threat tropical cyclones over 300 n mi away, may produce winds ≥ 22 kt at Pusan. Also evident from Figure VII-23 is the fact that passage over Japan acts to reduce the effects associated with the threat tropical cyclones.

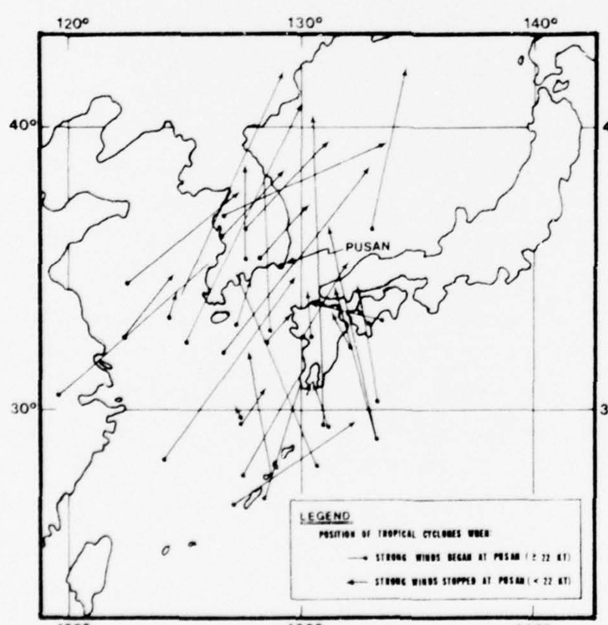

Figure VII-23. Positions of tropical cyclone centers when ≥ 22 kt winds first and last occurred at Pusan (based on data for June-October, 1948-73).

Figure VII-24 shows the positions of threat tropical cyclone centers when gale force ($\geq$ 34 kt) winds were first and last recorded at Pusan. It can be seen that winds $\geq$ 34 kt in Pusan result more from tropical cyclone passage to the west than to the east. It is felt that the most severe threat is associated with a passage just west of Pusan since the resulting southerly winds (especially from the southeast) are virtually unblocked before they reach the harbor. The maximum sustained wind velocity recorded at Pusan during June-October 1948-73 was 70 kt in 1959, the result of Typhoon Sarah's passage just 10 n mi west of Pusan. Typhoon Sarah had a maximum wind of approximately 90 kt as she made landfall. Military installations in Pusan/Taegu areas suffered almost a million dollars in damage, with damage to the port of Pusan alone exceeding $100,000.00.[3]

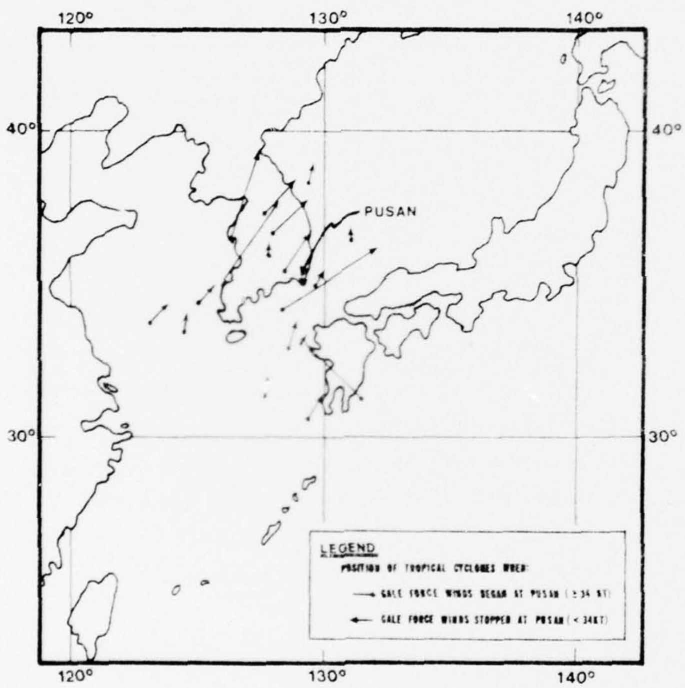

Figure VII-24. Positions of tropical cyclone centers when $\geq$ 34 kt winds first and last occurred at Pusan (based on data for June-October, 1948-73).

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[3] For a more detailed discussion on the effects of tropical cyclones on Pusan, see "An Evaluation of the Harbors of Inchon, Pusan and Chinhae, Republic of Korea as Typhoon Havens," by D. Rudolph, NAVENVPREDRSCHFAC Technical Paper No. 22-75, 1975.

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3.5.3 Wave Action

The maximum wave heights that can be expected with typhoon strength winds (≥ 64 kt) in Pusan's North Harbor are given in Table VII-4.

Table VII-4. Maximum wave heights that can be expected with typhoon strength winds (≥ 64 kt) in North Outer and Inner Harbor.

Location	North Outer Harbor	North Inner Harbor
Winds generally from the north (tropical cyclone passage east of Pusan)	4 ft	5 ft
Winds generally from the south (tropical cyclone passage west of Pusan)	12 ft	4 ft

Wave action in North Inner Harbor is minimal due to the short fetch. However, North Outer Harbor presents a fetch of about 100 n mi for winds out of the southeast, so high wave action can be expected if winds are from this direction.

3.5.4 Storm Surge And Tides

During periods of moderate to strong south to southeasterly winds (tropical cyclone passage west of Pusan), a surge effect is evident in the inner harbor. This is caused by wind stress on the water surface and the effects of atmospheric pressure reduction. When this surge effect coincides with high tide, an abnormal rise in water level occurs. The only serious damage reported as a result of this phenomenon was associated with Typhoon Sarah as the storm came onshore some 10 n mi west of Pusan in September 1959.

3.6 THE DECISION TO EVADE OR REMAIN IN PORT

3.6.1 Remaining In Port

Remaining in port is not the recommended course of action for the following reasons:

(1) North Inner Harbor provides little protection from northerly winds (tropical cyclone passage east of Pusan). As a matter of fact, the valley to the north of the harbor will act to increase the wind velocity by its funneling action.

(2) North Outer Harbor is exposed to southeasterly winds (tropical passage west of Pusan). In addition, the large fetch to the southeast can produce a sea state of up to 12 ft.

(3) A storm surge effect is possible and when combined with high tide, it may be dangerous.

3.6.2 Evasion

Evasion from Pusan Harbor is the preferred course of action under potentially threatening tropical cyclone conditions. The following evasion tactics are recommended:

(1) Evasion to the Sea of Japan

This evasion route takes the ship to higher latitudes where the intensity of the tropical cyclone decreases markedly. The Sea of Japan provides ample maneuvering room to place the ship in the navigable or "safe" semicircle of the tropical cyclone. This evasion route also allows a ship to cross to the Pacific Ocean from the Sea of Japan by means of Tsugaru Kaikyo between the southern tip of Hokkaido and the northern tip of Honshu.

It must be kept in mind when considering this tactic that unless done early, it is more than likely the tropical cyclone will overtake the ship since the speed of movement of the tropical cyclone once it enters the Sea of Japan often exceeds 30 kt. However, at the same time the intensity of the tropical cyclone decreases as it reaches the more northerly latitudes and the effects of the associated wind and sea will be much less intense than if the tropical cyclone is met at lower latitudes (see Para. 3, Chapter I).

(2) Evasion to Chinhae Bay north of Koje-Do (see Figure VII-14)

This is the evasion tactic used by the larger ROK Navy ships and is recommended if a need exists to remain in Korean waters. Chinhae Bay is a large, landlocked bay formed by the northwest side of Koje-Do and the mainland. The bay is entered from the east through the deep passage on either side of Cham-Do (see Figure VII-14). The bottom of the bay is predominantly mud and shell and provides a good anchor holding action. Protection from strong winds is available in the bay for winds from all directions.

The only reports of damage available from ships in Chinhae Bay during a typhoon were associated with Typhoon Sarah in 1959. This typhoon passed approximately 10 n mi to the west of Pusan with central winds in excess of 90 kt. Several vessels ran aground in Chinhae Bay because they were not properly anchored. The damage to Pusan Harbor was much more severe.

If the threatening tropical cyclone is forecast to have sustained winds greater than 110 kt, it would be more prudent to evade to the Sea of Japan.

(3) Other Evasion Routes

Other evasion routes at sea may be developed by the use of the FWC/JTWC warnings, Appendix I-A in Chapter I (the mean tropical cyclone tracks, track limits, and average speed of movements) and Figures VII-25 to VII-29.

The area enclosed by the threat axis depicted in Figures VII-25 to VII-29 represents a 30% or greater probability of being threatened by a tropical cyclone. Note how the orientation of the threat axis shifts from month to month.

To correctly assess the threat posed by an approaching tropical cyclone, the following timetable has been established in conjunction with Figures VII-25 to VII-29:

I. An existing tropical cyclone moves into or development takes place in area A with forecast movement toward Korea:

a. Decide whether evasion is to be at sea or to Chinhae Bay.

b. Review material condition of ship (destroyers should especially consider fuel). A sortie may be desirable 2-4 days hence.

c. Reconsider any maintenance that would render the ship incapable of getting underway within 48 hours.

II. Tropical cyclone enters area B with forecast movement toward Pusan:

a. All ships begin planning course of action to be taken if sortie should be ordered.

b. Reconsider any maintenance that would render the ship incapable of getting underway within 24 hours.

III. Tropical cyclone enters area C with forecast movement toward Pusan:

a. Execute sortie plans made in previous steps.

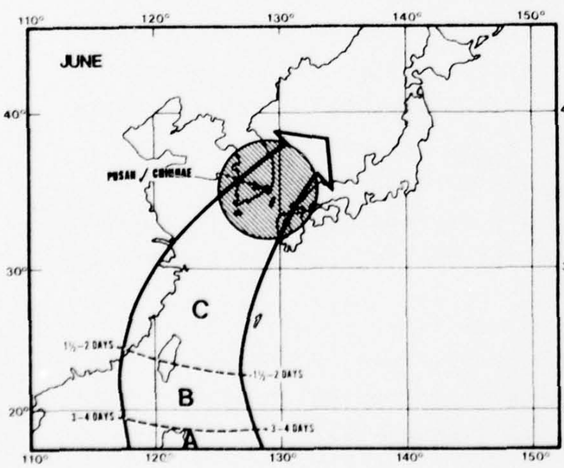

Figure VII-25. Tropical cyclone threat axis for June.

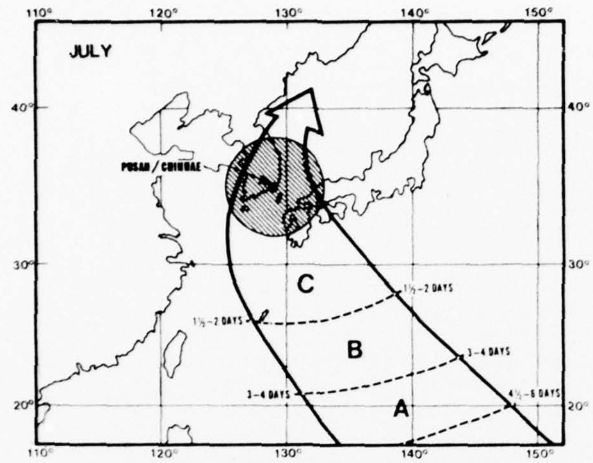

Figure VII-26. Tropical cyclone threat axis for July.

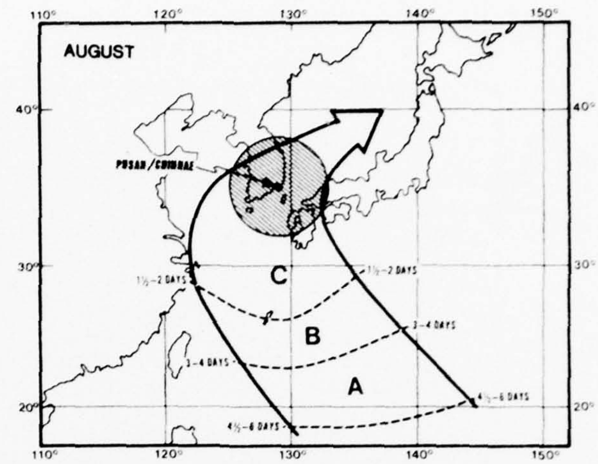

Figure VII-27. Tropical cyclone threat axis for August.

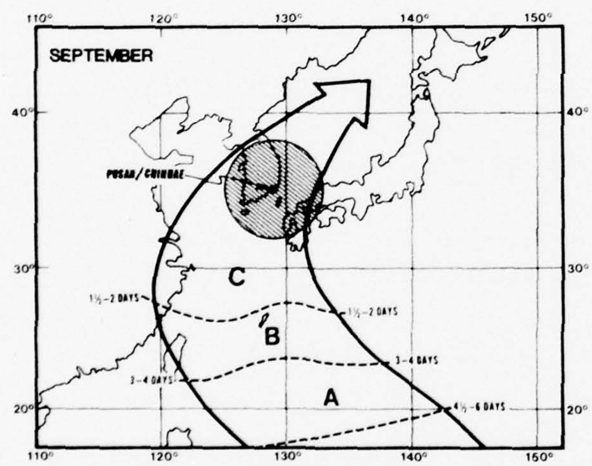

Figure VII-28. Tropical cyclone threat axis for September.

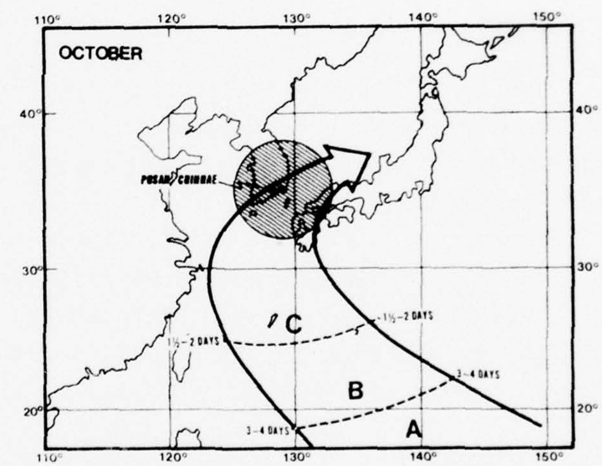

Figure VII-29. Tropical cyclone threat axis for October.

4. CHINHAE

SUMMARY

It is the recommendation of this study that U.S. Navy vessels (destroyer-size or smaller) remain in port and that larger vessels seek shelter in Chinhae Bay for tropical cyclone threat conditions with an expected maximum sustained wind at closest point of approach (CPA) up to 80 kt. If the tropical cyclone is forecast to have maximum sustained winds between 80-110 kt, the destroyer-size or smaller vessels should also seek shelter in Chinhae Bay. If the tropical cyclone is forecast to have maximum sustained winds greater than 110 kt, evasion to the Sea of Japan is recommended.

4.1 LOCATION

Chinhae Harbor, located at 35°08'N, 128°41'E on the southeast coast of the Korean Peninsula, is the site of the Republic of Korea's principal naval base (see Figure VII-14). The port of Pusan is less than 20 n mi due east from Chinhae Harbor.

4.2 CHINHAE HARBOR

The harbor has four piers and four quays that are used by the ROK Navy. The usual berth for visiting ships is a quay constructed of stone and concrete, designated as pier 2. Pier 2 has two distinct berths with a depth of 25 ft at mean low tide.

Within the harbor 24 mooring buoys (reserved for ROK Navy) and 39 anchorages (all in five to six fathoms of water) are available. Anchorages Z-1 and Z-2 are normally assigned to U.S. Navy ships.

The tidal range in the harbor is 6-8 ft and tidal currents of 1-1/2 kt can be expected in the approach channel.

4.3 TOPOGRAPHY

Chinhae Harbor is well protected by hills on all sides except to the south and southeast where it faces the ocean (see Figures VII-14 and VII-30). However, protection is provided to the south by the hills on Koje-Do. Only to the southeast is there no protection from winds.

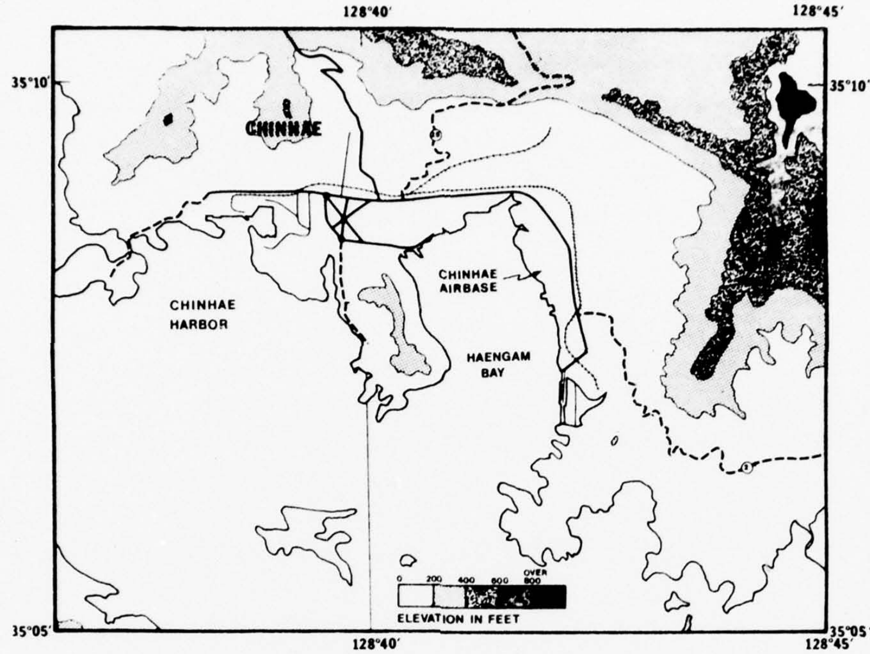

Figure VII-30. Chinhae Harbor and surrounding topography.

4.4 HARBOR FACILITIES

The ROK Navy shipyard has one drydock which can accommodate ships up to 2,250 tons. In addition, one 50-ton and two 30-ton floating cranes, as well as 15-ton and 20-ton mobile cranes (one each), are available for service to visiting ships. For a detailed description of harbor facilities available in Chinhae, refer to CINCPACFLT Port Directory.

4.5 TROPICAL CYCLONES AFFECTING CHINHAE

4.5.1 Tropical Cyclone Climatology For Chinhae

Refer to Paragraph 3.5.1 (Pusan section) for the tropical cyclone climatology of Chinhae.

4.5.2 Wind And Topographical Effects

Maximum winds can be expected from the southeast of Chinhae since little topographic protection is available from this direction. Southeasterly winds would be associated with threat tropical cyclone passage to the west of Chinhae.

Wind observations from the Chinhae Air Base were analyzed to determine the extent to which threat tropical cyclones produced strong winds (≥ 22 kt) or gale force winds (≥ 34 kt) at Chinhae. The air base is located on the east side of Haengam Bay (35°08'N, 128°42'E; see Figure VII-30) adjacent to Chinhae Harbor, and winds recorded at the base are representative of the wind conditions existing in Chinhae Harbor for all directions except to the south-southeast and west-northwest. Winds from these directions will be 10-20% less at the airfield due to the protection provided by the two points forming Haengam Bay. Unfortunately, hourly wind observations were only available for the period 1951-61.[4]

Twenty-one tropical cyclones came within 180 n mi of Chinhae in this 11-year period (June-October), about two per year. Table VII-5 groups the tropical cyclones that threatened Chinhae during this period according to the wind intensity that they produced at Chinhae. Of the 21 threat tropical cyclones, only 33% resulted in strong winds (≥ 22 kt) and 24% resulted in gale force winds (≥ 34 kt). From analyses of the threat tropical cyclones, it is apparent that they produced gale force winds only during August and September.

Table VII-5. Extent to which threat tropical cyclones affected Chinhae during June-October, 1951-61.

Number of tropical cyclones that threatened Chinhae	21	--
Number of threat tropical cyclones resulting in strong (≥ 22 kt) winds in Chinhae	7	33%
Number of threat tropical cyclones resulting in gale force (≥ 34 kt) winds in Chinhae	5	24%

Figure VII-31 shows the positions of threat tropical cyclone centers when strong ≥ 22 kt winds were first and last recorded at Chinhae Air Base. It is evident that threat tropical cyclones as far away as 340 n mi may produce winds ≥ 22 kt at Chinhae.

Figure VII-32 shows the positions of tropical cyclone centers when gale force (≥ 34 kt) winds were first and last recorded at Chinhae Air Base. It can be seen that winds ≥ 34 kt generally do not begin until the storm is at about 33°N latitude.

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[4]This 11-year period represents a very small data base, so caution must be used in applying the conclusions derived from this data.

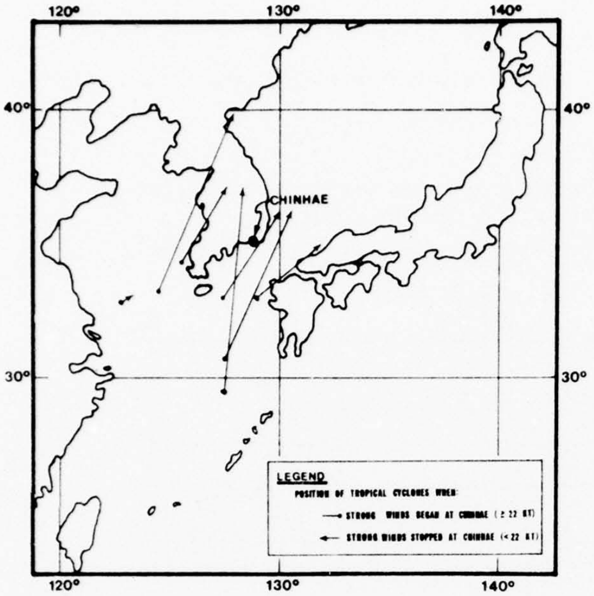

Figure VII-31. Positions of tropical cyclone centers when $\geq$ 22 kt winds first and last occurred at Chinhae (based on data for June-October, 1951-61).

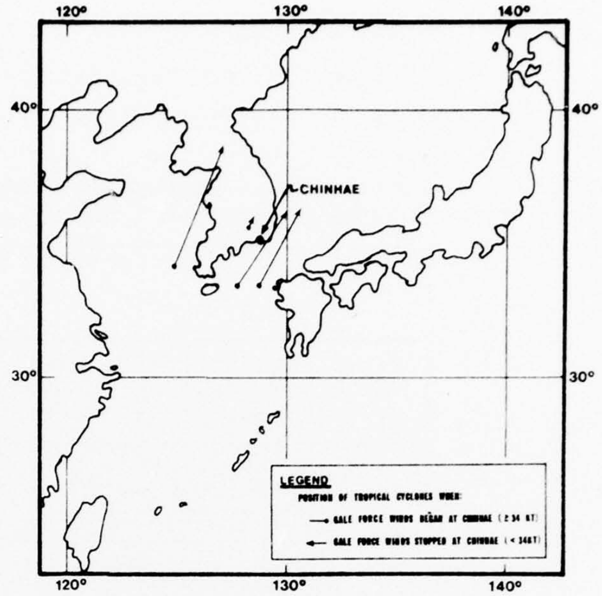

Figure VII-32. Positions of tropical cyclone centers when $\geq$ 34 kt winds first and last occurred at Chinhae (based on data for June-October, 1951-61).

The maximum sustained winds recorded at Chinhae Air Base resulted from Typhoon Sarah, which passed 10 n mi to the east with maximum sustained winds over 90 kt in 1959. The maximum winds at Chinhae were from the northeast at 55 kt. Figure VII-30 indicates the presence to the northeast of hills over 600 ft which acted to reduce the wind intensity. It is felt that the most severe threat to the harbor occurs when a tropical cyclone approaches from the southwest and passes west of Chinhae within 30 n mi. In this case the strongest winds would be from the southeast. There is almost no topographical protection available from this direction, and the full force of the typhoon might be felt. As the typhoon comes onshore it would weaken rapidly and its associated winds would also decrease.[5]

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[5] For a more detailed discussion on the effects of tropical cyclones on Chinhae, refer to "An Evaluation of the Harbors of Inchon, Pusan and Chinhae, Republic of Korea as Typhoon Havens," by D. Rudolph, NAVENVPREDRSCHFAC Technical Paper No. 22-75, 1975.

4.5.3 Wave Action

The maximum wave heights that can be expected with typhoon strength winds (≥ 64 kt) in Chinhae Harbor are given in Table VII-6.

Table VII-6. Maximum wave heights that can be expected with typhoon strength winds (≥ 64 kt) in Chinhae Harbor.

Location	Northern Part of Harbor	Southern Part of Harbor
Winds generally from the north (tropical cyclone passage east of Chinhae)	3 ft	4 ft
Winds generally from the south (tropical cyclone passage west of Chinhae)	10 ft	8 ft

4.5.4 Storm Surge And Tides

During periods of moderate to strong southeasterly winds (tropical cyclone passage west of Chinhae), a surge effect is evident in the inner harbor as a result of wind stress on the water surface and the effects of atmospheric pressure reduction. When this surge effect coincides with high tide, an abnormal rise in water level may occur.

4.6 THE DECISION TO EVADE OR REMAIN IN PORT

4.6.1 Evasion Rationale

For most tropical cyclone threat situations, remaining in port or seeking shelter in Chinhae Bay is the recommended course of action for all ships. For the rare severe tropical cyclone (> 110 kt maximum sustained wind) threatening Chinhae, it would appear to be more prudent to evade to the Sea of Japan. Typically, threat tropical cyclones pass Chinhae with maximum winds in the 40-70 kt range.

To correctly assess the threat posed by an approaching tropical cyclone the following timetable has been established in conjunction with Figures VII-25 through VII-29 in the Pusan section:

I. An existing tropical cyclone moves into or development takes place in area A with forecast movement toward Korea:

  a. Review material condition of ship. A sortie may be desirable 2-4 days hence.

  b. Reconsider any maintenance that would render the ship incapable of getting underway in 48 hours.

II. Tropical cyclone enters area B with forecast movement toward Chinhae:

a. All ships begin planning course of action should sortie be ordered.

b. Reconsider any maintenance that would render the ship incapable of getting underway within 24 hours.

III. Tropical cyclone enters area C with forecast movement toward Chinhae:

a. If destroyer size or smaller and tropical cyclone is forecast to have maximum winds less than 80 kt CPA, remain in port. Larger vessels should seek protection in Chinhae Bay.

b. If tropical cyclone is forecast to have maximum sustained winds between 80-110 kt at CPA, all vessels should seek protection in Chinhae Bay.

c. If tropical cyclone is forecast to have maximum sustained winds greater than 110 kt, recommend evasion to the Sea of Japan.

4.6.2 Remaining In Port

Remaining in port is the recommended course of action for ships of destroyer size or smaller for most tropical cyclone threat conditions. Larger vessels will find protection available in Chinhae Bay. The bottom of the bay is predominantly mud and shell and provides good holding action. The bay also provides wind protection from all directions.

The only blemish on Chinhae Harbor's record as a typhoon haven was the result of Typhoon Sarah, which passed approximately 10 n mi to the east of Chinhae with maximum winds of about 90 kt in 1959. The mountains surrounding Chinhae were effective in reducing the winds substantially (55 kt winds were observed from the NE), but even so, several ROK Navy vessels were damaged when they ran aground. Thus, if the winds of a tropical cyclone are forecasted to be greater than 80 kt, it would be prudent for the destroyer size or smaller ships also to seek shelter in Chinhae Bay. In the rare event that wind intensities greater than 110 kt are predicted, evasion to the Sea of Japan would be recommended. It should also be noted that Typhoon Sarah caused several ships in Chinhae Bay to go aground because they were improperly anchored.

4.6.3 Evasion

Evasion from the Chinhae area is not necessary under most tropical cyclone threat situations. Based on limited data available, it appears that only if the tropical cyclone is forecast to have a maximum wind at CPA of greater than 110 kt would evasion be necessary to the Sea of Japan. This evasion route takes the ship to higher latitudes where the intensity of the tropical cyclone decreases markedly. The Sea of Japan provides ample maneuvering room to place the ship in the navigable or "safe" semicircle of the tropical cyclone. This evasion route also allows a ship to cross to the Pacific Ocean from the Sea of Japan by means of Tsugaru Kaikyo between the southern tip of Hokkaido and the northern tip of Honshu.

It must be remembered when considering this tactic that unless done early, it is more than likely the tropical cyclone will overtake the ship since the speed of movement of the tropical cyclone once it enters the Sea of Japan often can be in excess of 30 kt. However, at the same time, the intensity of the tropical cyclone decreases as it reaches the more northerly latitudes and the effects of the associated wind and sea will be much less intense than if the tropical cyclone is met at lower latitudes.

SECTION VIII - CONTENTS

VIII SRI LANKA

1. GENERAL

Sri Lanka (formerly Ceylon) is an island nation situated in the Indian Ocean just southeast of India (Figure VIII-1). Its area of 25,332 square miles is slightly greater than that of West Virginia. Lying but a few degrees north of the equator, it has a tropical climate, warm and humid at sea level but cool and pleasant in the south central highlands.

Colombo, the capital, largest city and principal port lies on the west coast at 6°57'N, 79°51'E. Colombo has an artificial harbor which provides excellent accommodations for vessels up to 40,000 tons.

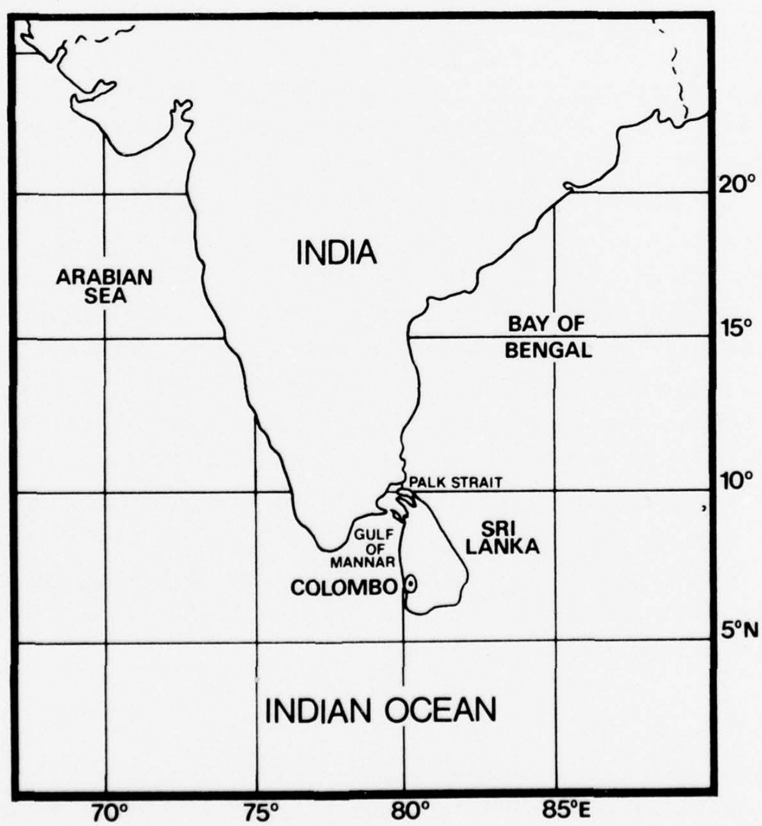

Figure VIII-1. Locator map.

Chg 1

2. COLOMBO

SUMMARY

Colombo can be considered a typhoon haven for most tropical cyclone threat situations. Since almost all of the tropical cyclones that threaten Colombo come from the east (94%), the location of Colombo provides excellent protection from storm-associated winds. In addition, tropical cyclones crossing the island diminish greatly in intensity. Although such an occurrence is rare at these low latitudes, if an intense tropical cyclone (greater than 100 kt maximum wind) approached from the east, evasive action to the south would be recommended. The one tropical cyclone that affected Colombo the most in the last 26 years approached from the west and contributed 50 kt sustained winds to the harbor as it passed some 50 n mi to the north. The most dangerous situation for Colombo is the developing tropical cyclone just to the southwest of Sri Lanka, which would make evasion difficult. In the last 26 years only two tropical cyclones have developed to the southwest of Sri Lanka; one moved west, the other northeast.

2.1 LOCATION AND TOPOGRAPHY

Sri Lanka is an extension of the south Indian plateau. It is separated from India by Palk Strait (20 statute miles (32 km) wide at its narrowest) and by the Gulf of Mannar (Figure VIII-2). Mannar Island, off Sri Lanka's northwest coast, and the nearby shallows known as Adam's Bridge virtually connect the island to the mainland. Sri Lanka's greatest length is 270 statute miles (435 km) and its widest point is 140 statute miles (225 km).

Sri Lanka has three main topographical regions: the mountains, the coastal plain and the coast (Figure VIII-2). The mountains in the south central section rise to jagged peaks 7000 to 8000 ft (2100-2400 m) high. Highest is Pidurutalagala (Mount Pedro) at 8291 ft (2527 m). Best known of the peaks is Sri Pada (Adam's Peak), 7360 ft (2243 m), a landmark that was familiar to ancient navigators. A coastal plain in the island's southern section broadens into an extensive flat, dry region north of the mountains. The coasts are rimmed by sandy beaches. The force of the surf is diminished by coral reefs, sand banks and shoals. The only great natural harbor is at Trincomalee on Koddiyar Bay on the northeast coast.

2.2 COLOMBO HARBOR

Colombo Harbor is approximately 1 1/4 n mi in length and 1/2 n mi in width and is totally enclosed except for the two entrances. It is an artificial harbor (see Figure VIII-3).

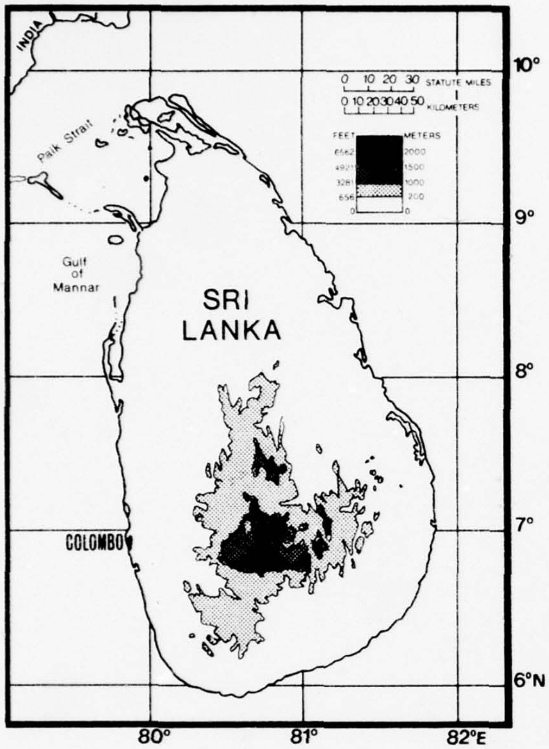

Figure VIII-2. Topographical map of the island nation of Sri Lanka.

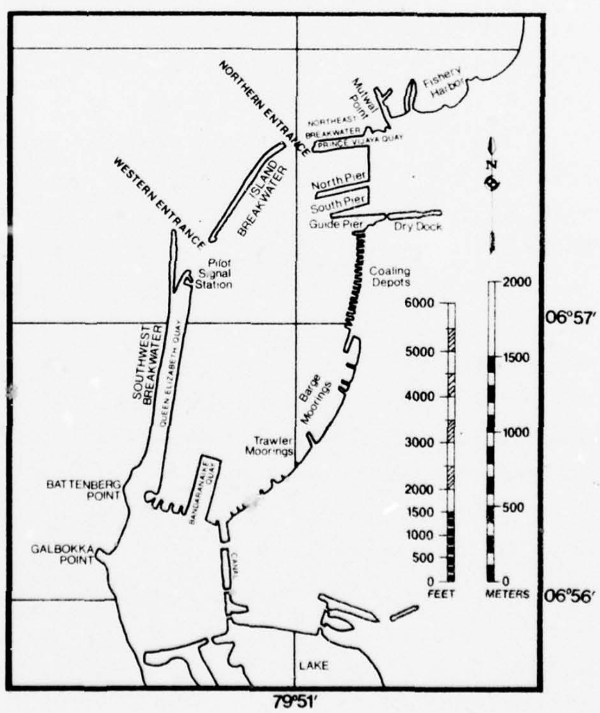

Figure VIII-3. Colombo Harbor.

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Unless otherwise directed by the Master Attendant, Colombo, entrance to Colombo Harbor is to be made via the western entrance (also known as Southwest Breakwater Gate). This entrance is approximately 750 ft (229 m) wide and has a controlling depth of 34 ft (10.4 m). In the summer, the clearance between the breakwaters through this entrance can be a problem for large ships for a turn to a northern berth in the vicinity of Guide Pier, because of the heavy westerly and southwesterly swell near this entrance during the southwest monsoon.

The remaining entrance, the northern, is about 630 ft (192 m) wide and has an entrance depth of 33 ft (10.1 m). The possibility exists that by 1980 the northern entrance will be closed off.

Depths over 30 ft (9.1 m) are indicated for the greater part of the harbor. Vessels are not permitted to navigate within the harbor, or to lie at moorings, or berth alongside with less than 2 ft (0.61 m) under their bottoms, except by special permission of port authorities. Ordinarily the maximum permissible length for use of the harbor is 800 ft (244 m). Maximum draft permitted alongside is 34 ft (11.0 m).

Several alongside berths are available within the harbor for deep-draft vessels and there are moorings for large and small vessels. Vessels moor between two mooring buoys with anchor forward and buoy aft. Buoys are secured by chains and are designed to take normal loads almost indefinitely. During the southwest monsoon, vessels secure head and stern between mooring buoys, heading westward with their port anchor down. During the northeast monsoon, vessels secure head and stern between mooring buoys, heading northward, with their port anchor down. Vessels using Colombo Harbor should be prepared to use both anchors. The bottom is mud and the holding is considered good.

Vessels awaiting berths or not wishing to enter the harbor should anchor about 1 1/2 n mi north-northwest of the western entrance. Vessels are requested not to anchor within one mile of harbor entrances. Depths range from 5 1/2 to 10 3/4 fathoms with fair to good holding of mud and sand.

The southwest monsoon brings heavy rain and winds which occasionally reach gale force (34 kt or greater). During this period a moderate swell runs near the harbor.

The land is low in the vicinity of Colombo Harbor and will not be visible from any great distance. Radar navigation is difficult because of the low profile of the coast and lack of prominent features near Colombo. In exceptionally clear weather, Adams Peak (Sri Pada) and the other mountains may be seen from great distances.

2.3 TROPICAL CYCLONES AFFECTING COLOMBO

2.3.1 Tropical Cyclone Climatology for Colombo Harbor

The majority of the tropical cyclones that pose a threat to Colombo (any tropical cyclone approaching within approximately 180 n mi is considered a "threat") occur during the months November-January. Figure VIII-4 is a monthly summary of threat situations based on data from 1950-75. In Figure VIII-5, these threat tropical cyclones are displayed according to the compass octant from which they approached Colombo; it is readily seen that the majority of storms approach from the north-northeast to east-southeast.

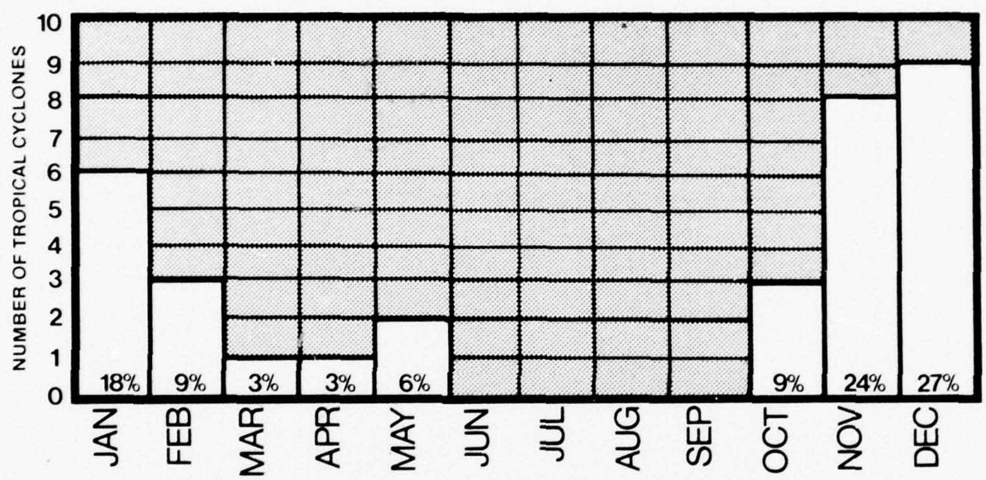
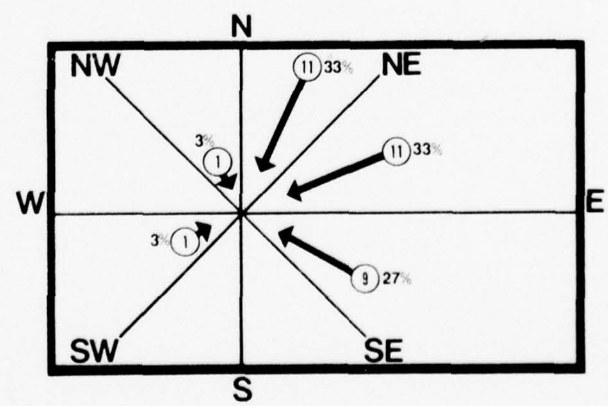


Figure VIII-4. Monthly frequency distribution of the number of tropical cyclones that passed within approximately 180 n mi of Colombo (based on data from 1950-75).

Figure VIII-5. Direction of approach to Colombo of the tropical cyclones (1950-75) that passed within approximately 180 n mi of Colombo. The circled numbers indicate the total number of storms that approached from each octant. The percentages are those of the total sample (33) that approached from each octant.



Chg 1

COLOMBO

Figures VIII-6 through VIII-11 show the percentages of tropical cyclones that have passed within approximately 180 n mi of Colombo (can be interpreted as the probability of threat) for the period January-May and October-December. The dashed lines represent approximate approach times to Colombo based on a typical approach speed of 6-8 kt. For example, in Figure VIII-6 a storm located at 5N,85E has an 80% probability of passing within 180 n mi of Colombo and, if its speed remains in the 6-8 kt range, it will reach Colombo in 1 1/2-2 days.

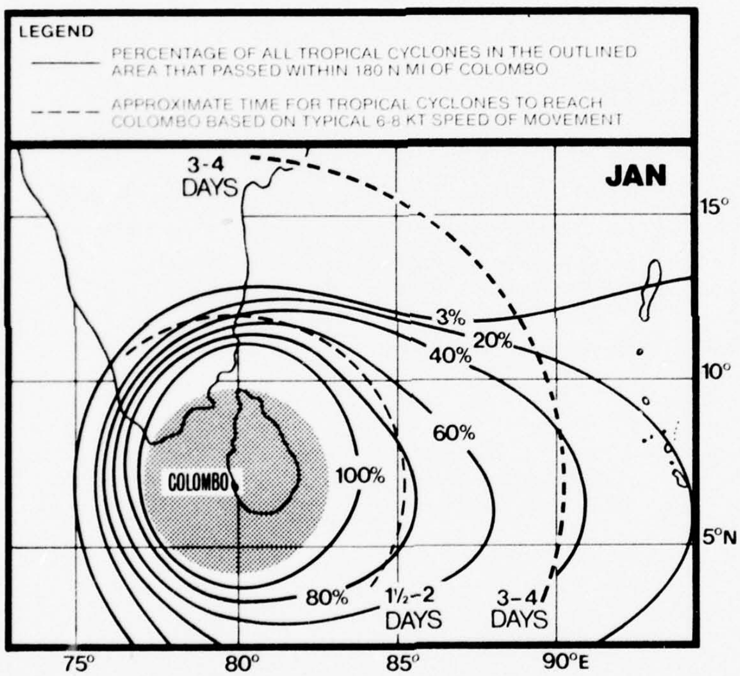


Figure VIII-6. Probability that a tropical cyclone will pass within approximately 180 n mi of Colombo (shaded area) in the month of January (based on data from 1950-75).

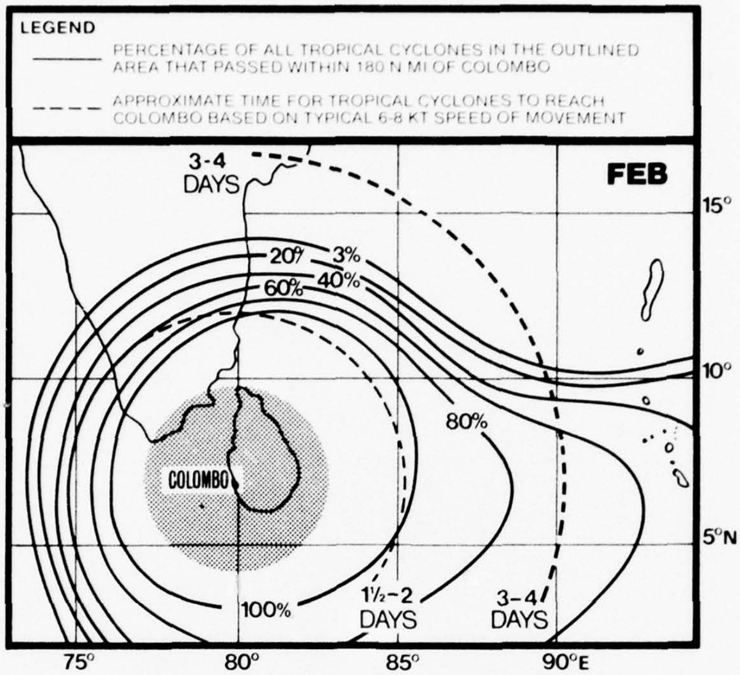


Figure VIII-7. Probability that a tropical cyclone will pass within approximately 180 n mi of Colombo (shaded area) in the month of February (based on data from 1950-75).

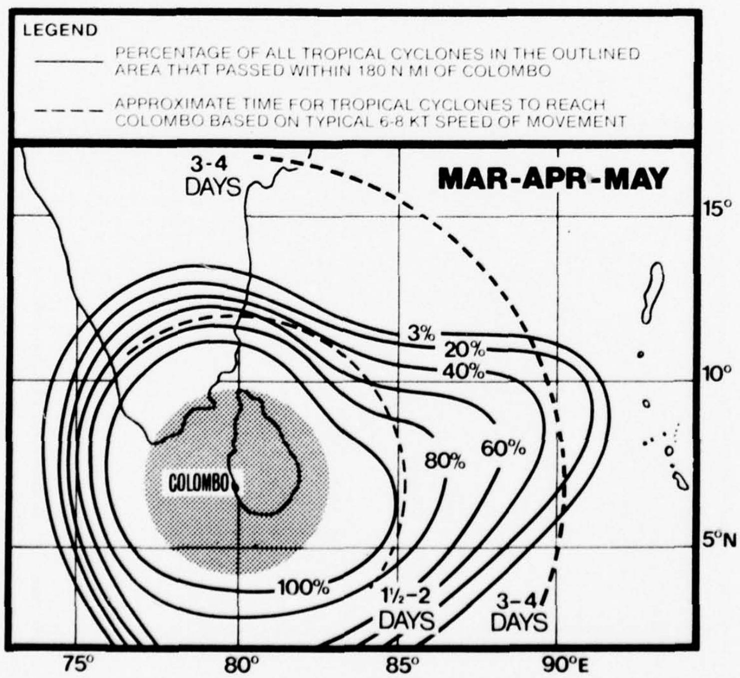


Figure VIII-8. Probability that a tropical cyclone will pass within approximately 180 n mi of Colombo (shaded area) in the months of March-April-May (based on data from 1950-75).

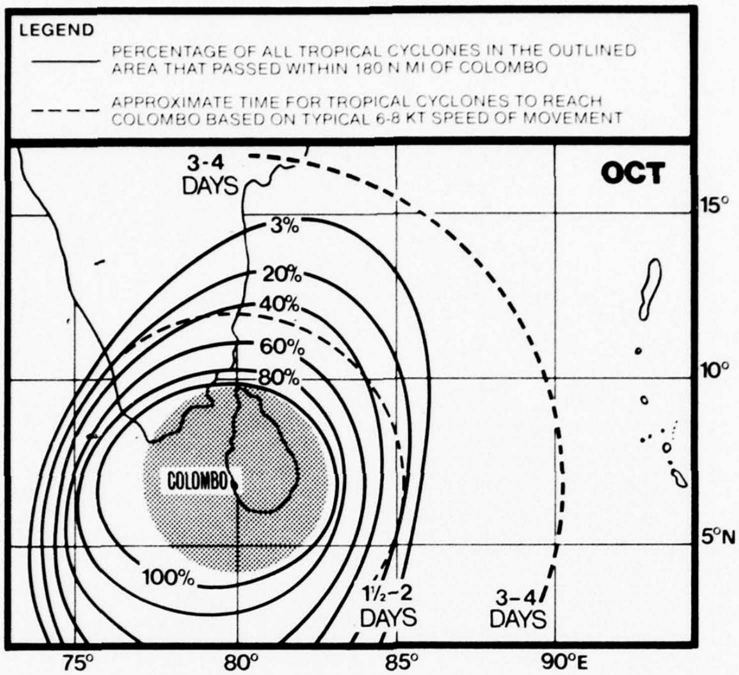


Figure VIII-9. Probability that a tropical cyclone will pass within approximately 180 n mi of Colombo (shaded area) in the month of October (based on data from 1950-75).

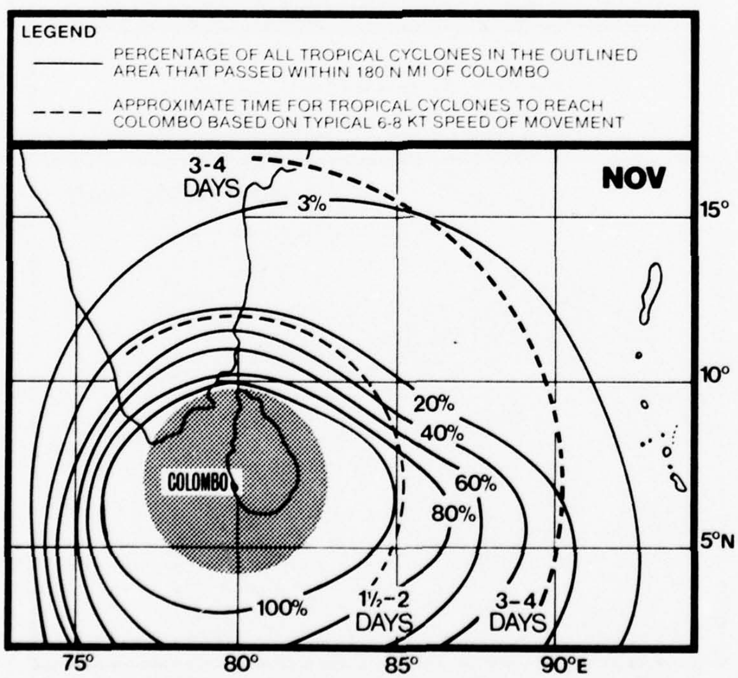


Figure VIII-10. Probability that a tropical cyclone will pass within approximately 180 n mi of Colombo (shaded area) in the month of November (based on data from 1950-75).

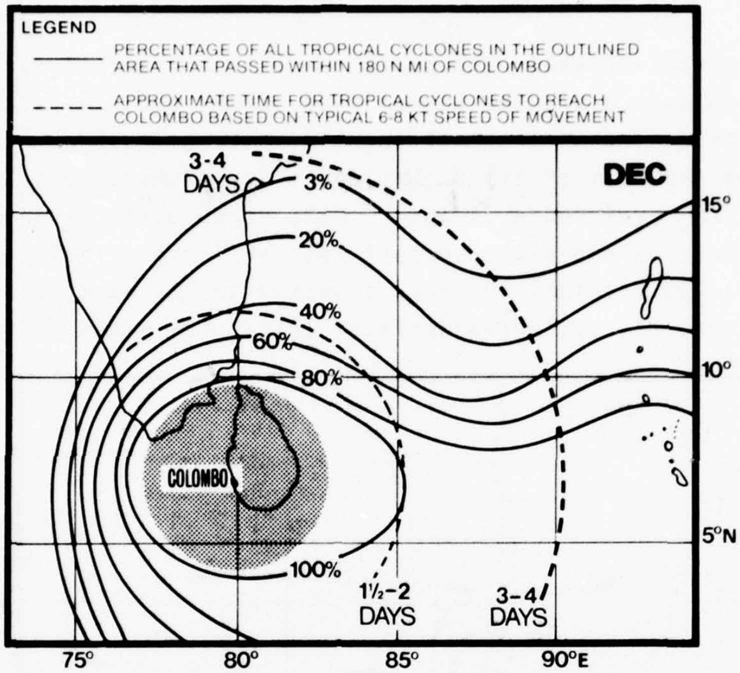


Figure VIII-11. Probability that a tropical cyclone will pass within approximately 180 n mi of Colombo (shaded area) in the month of December (based on data from 1950-75).

In the period examined, an average of slightly more than one tropical cyclone a year passed within approximately 180 n mi of Colombo. It should be noted, however, that in the year 1967, eight tropical cyclones passed within 180 n mi of Colombo! In Table VIII-1, the 27 tropical cyclones which passed within approximately 180 n mi from Colombo in the period 1950-69 are grouped according to their effect on Colombo. Notice that only two of the 27 tropical cyclones contributed to sustained winds of $\geq$34 kt.

Table VIII-1. Extent to which tropical cyclones affected Colombo during the period 1950-69. Wind data is from Pilot Station, Colombo Harbor.

Number of tropical cyclones that passed within approximately 180 n mi at Colombo	27
Number of tropical cyclones that resulted in winds $\geq$ 22 kt winds at Colombo	12 (44%)
Number of tropical cyclones that resulted in winds $\geq$ 34 kt winds at Colombo	2 (7%)

Figure VIII-12 shows the positions of the tropical cyclone track segments (1950-69 data discussed above) when strong winds ($\geq$ 22 kt) were recorded at Colombo. Most of the strong wind situations occurred with tropical cyclones just to the east of Sri Lanka, and a few cases show $\geq$ 22 kt winds at Colombo with storms over 300 n mi away. Gale force winds ($\geq$ 34 kt) have occurred with the tropical cyclones just west or north of Sri Lanka (see Figure VIII-13). No tropical cyclones situated to the east of Sri Lanka contributed to tropical cyclone-associated gale force winds at Colombo.

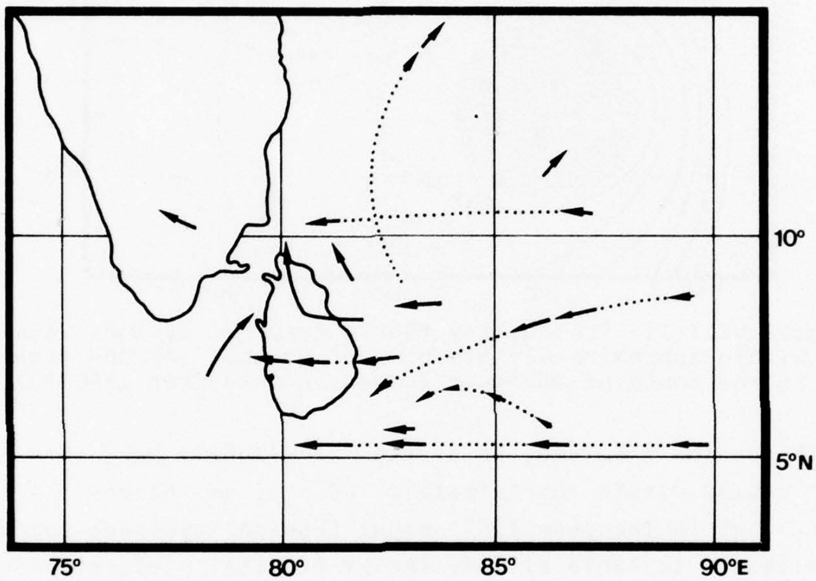
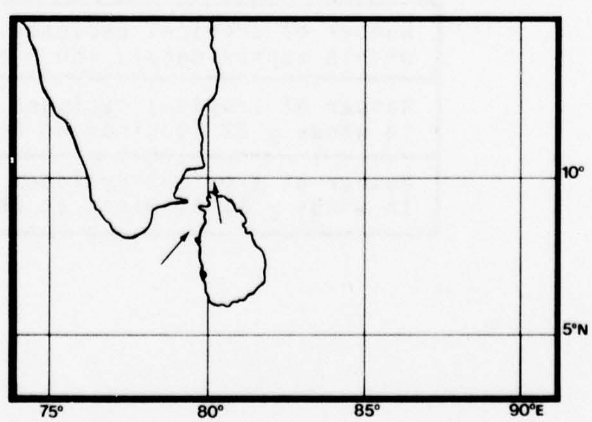


Figure VIII-12. Track segments for tropical cyclones which contributed sustained winds greater than or equal to 22 kt at Colombo. Solid lines indicate actual occurrences, while dotted lines connect track segments with more than one such occurrence. (Data from 1950-69 supplied by Meteorological Department, Sri Lanka.)

Figure VIII-13. Track segments for tropical cyclones contributing sustained winds greater than or equal to 34 kt at Colombo. (Data from 1950-69 supplied by Meteorological Department, Sri Lanka.)



2.3.2 Effects of Topography

Almost all of the tropical cyclones threatening Colombo approach from the east. Because Colombo's location is on the west coast, any tropical cyclone crossing the island from the east loses much of its intensity before reaching Colombo.[1] Occasionally a tropical cyclone, moving east to west, passes south of the island, but it will not affect Colombo until it is to the southwest of Colombo. Since these storms are close to the equator, they are not very intense. Tropical cyclones passing east to west to the north of Sri Lanka are influenced by Indian subcontinents and their effects are thereby diminished. Possibly the worst threat is posed by those rare tropical cyclones developing to the southwest of Colombo. Two such storms were found in the period examined (1950-75): one moved to the west (away from Colombo), but the other headed northeast and passed approximately 50 n mi northwest of Colombo, producing nearly 50-kt winds at Colombo Harbor. A closer passage could have severely damaged the harbor. It should be noted that approximately 75% of the threat tropical cyclones examined passed north of Colombo.[2]

2.4 THE DECISION TO EVADE OR REMAIN IN PORT

2.4.1 Evasion Rationale

A most important aspect of any decision concerning heavy weather is an early appraisal of the threat posed by an individual tropical cyclone. Precautions must be taken when enough time remains to allow flexibility in the preparedness or evasion plan. Some rough guidelines that might be of use are presented on the following page in conjunction with Figure VIII-14.

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[1] An intense tropical cyclone in December 1964 crossed the island from the east near latitude 9°N with winds near the center of approximately 110 kt at landfall. The winds at Colombo did not exceed 30 kt.

[2] For a detailed general discussion of the environmental phenomena in the Bay of Bengal, refer to "A Handbook for Forecasters in the Bay of Bengal," Naval Environmental Prediction Research Facility Technical Paper No. 7-73, 1973.

I. An existing tropical cyclone moves into or significant development takes place in area A with forecast movement toward Colombo:

a. Review material condition of ship. A sortie may be desirable 2-4 days hence.

b. Reconsider any maintenance that would render the ship incapable of getting underway within 48 hours.

c. Plot FWC/JTWC, Guam, warnings.

II. Tropical cyclone moves into or significant development takes place in area B with forecast movement toward Colombo:

a. Consider possible course of action if sortie is decided.

b. Reconsider any maintenance that would render the ship incapable of getting underway within 24 hours.

c. Plot FWC/JTWC, Guam, warnings.

d. Prepare ship for heavy weather.

III. Tropical cyclone enters area C with forecast movement toward Colombo:

a. Ensure sufficient power available to counter high winds (see Para. 5, Chapter I).

b. If tropical cyclone maximum wind is 100 kt or greater, sortie south.

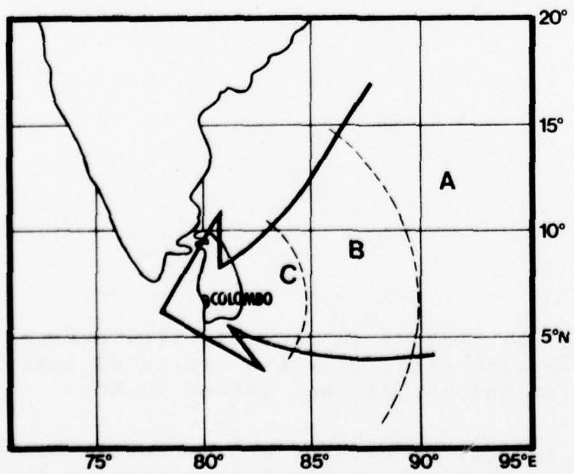

Figure VIII-14. Tropical cyclone threat axis for Colombo. Approach times are measured from Colombo and are based on typical 6-8 kt forward speeds of movement for tropical cyclones affecting Colombo.

2.4.2 Remaining in Port

Remaining in port, in almost all instances, is the recommended course of action when a tropical cyclone threatens Colombo. The following items must be considered:

(1) Berth assignments should be accomplished before 25 kt winds begin.

(2) Tropical cyclones passing to the north will contribute north to northwesterly winds, while passage to the south will contribute southeast to southwesterly winds.

(3) A storm approaching from the west is the most dangerous situation (considered rare - one case in 26 years of data examined) and will contribute to strong southerly and westerly winds.

(4) The effect of the wind is the most important factor to consider. The highest sustained wind associated with a tropical cyclone at Colombo (27 years of data) was approximately 50 kt. The effects of wave action and storm surge are negligible in Colombo Harbor. The highest waves ever observed in the harbor were about 3 ft.

(5) If crowded conditions within the harbor exist, the ship may elect to evade as a safer course of action.

(6) With strong northerly winds, maneuvering in the northern section of the harbor is difficult as compared to the southern section of the harbor. The harbor offers slightly more protection for southerly or southwesterly winds as compared to northerly or northwesterly winds.

2.4.3 Evasion at Sea

The widely held doctrine of evasion -- putting to sea rather than remaining in port for the single purpose of minimizing tropical cyclone-related damage -- is not generally recommended for vessels in port at Colombo. However, if putting to sea is desired, each tropical cyclone must be individually considered as differing from those preceding it and the synoptic situation at the time must be fully understood. It is not practical to establish one technique or rule to avoid the danger area.

Evasion from Colombo is short, direct and straightforward for any threat from a tropical cyclone coming from the east: head south. This keeps the ship in the navigable semicircle. If a tropical cyclone develops or moves in from the west, a southerly evasion route is also recommended only if the ship can keep clear of the danger area (see Para. 7, Chapter I).

It should be noted that most tropical cyclones in low latitudes are smaller than those at higher latitudes and thus the areal extent of the strong winds and seas will not be as great. In addition, the speed of movement of the storms is slower in the North Indian Ocean as compared with western North Pacific Ocean tropical cyclones. The effects of sea/swell on the speed of advance of a ship are discussed in Para. 5, Chapter I.

3. SOME COMMENTS ON STRONG WIND CONDITIONS AFFECTING COLOMBO (Other than associated with tropical cyclones)

The predominant wind direction during the winter is northeasterly, with the direction becoming northwesterly during the afternoon hours. Winds also tend to increase in velocity toward a late afternoon maximum. Sustained winds can typically reach 25 kt, but only once or twice a month will they reach $\geq$ 34 kt (gale force).

The winds in the summer are generally southwesterly and occasionally westerly. The winds tend to be more constant in the summer than in the winter and are slightly stronger in the afternoon hours as the sea breeze enhances the southwest monsoonal flow. During summer, sustained winds can typically reach 20-25 kt, but only two or three times a month will they reach $\geq$34 kt (gale force). Some of these strong winds are associated with squall lines. It should be noted that the harbor is more sheltered from the summer southwesterly winds than from the winter wind directions.

Colombo is affected by high swell during the summer and sometimes fall. Seas up to 15-20 ft can be experienced outside Colombo Harbor while the seas inside the harbor will be only 3 ft. Pilots will probably not board vessels with seas of 15 ft or greater.

Entry into the harbor with $\geq$ 30 kt winds or departure with $\geq$ 40 kt winds is not recommended.

The highest sustained wind ever recorded at Colombo was 63 kt (west-northwest) in June 1945; this was probably associated with a squall line.

SECTION IX - CONTENTS

IX PAKISTAN

1. GENERAL

Pakistan is situated on the northern shore of the Arabian Sea (Figure IX-1) with Iran its western neighbor, Afghanistan to the north and India to the east. Its area is about that of Texas and Louisiana combined. The countryside is mostly mountainous, with the exception of the eastern plain through which the Indus River flows to a delta just south of Karachi. Karachi (24°47'N, 66°59'E) is Pakistan's principal port and rail terminal on the Arabian Sea.

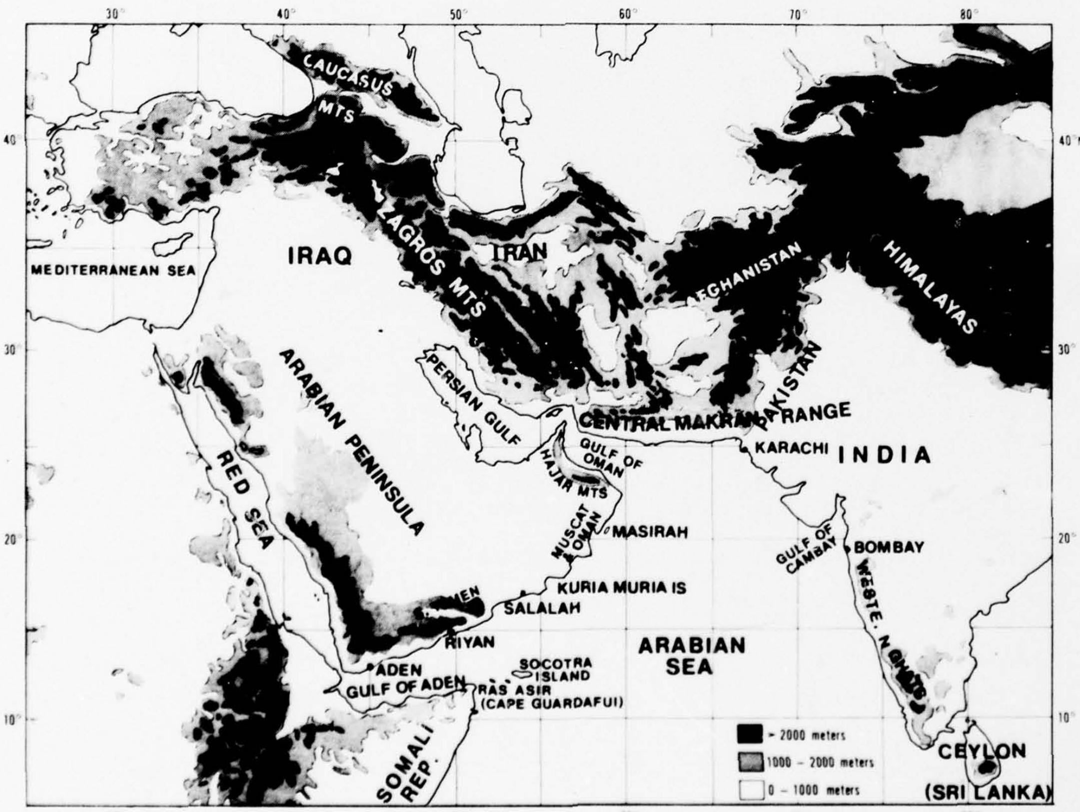

Figure IX-1. Locator map.

2. KARACHI

SUMMARY

In almost all tropical cyclone threat situations (about once a year), Karachi can be considered a tropical cyclone haven. This conclusion is based on the following:

1. The highest sustained wind associated with a tropical cyclone in the 1950-76 period was 45 kt.

2. Approximately 75% of the tropical cyclones that came within 180 n mi of Karachi were tropical cyclone depressions with maximum winds less than 34 kt.

3. The harbor provides excellent protection from the high seas associated with a tropical cyclone and some protection from the winds.

4. The mooring buoys are secure for winds up to 50 kt for almost all types of ships.

The only severe threat to a ship in Karachi Harbor would be an intense tropical cyclone in the Arabian Sea (rare), forecast to move northward. Under these conditions the following should be considered:

1. A tropical cyclone approaching from the south would make evasion difficult from Karachi. An early appraisal of the threat is important.

2. The wind protection afforded by the surrounding topography would not be enough to offset the damaging effects of a tropical cyclone passing in close proximity to Karachi with a maximum wind of 70 kt or greater.

3. A crowded harbor like Karachi, with holding varying greatly from poor to good, would be dangerous in a 70 kt wind.

Thus the only situation that would make Karachi a poor tropical cyclone haven would be in the case of a threat tropical cyclone with 70 kt or greater maximum wind.

2.1 GENERAL DESCRIPTION OF KARACHI HARBOR

The harbor, which occupies the lower part of Chinna Creek, has been widened, deepened and considerably improved. It is divided into a lower and upper harbor (see Figures IX-2 and IX-3) with principal commercial facilities located on both sides of the upper harbor. The harbor is narrow (minimum 250 yd (229 m) -- maximum 500 yd (457 m)) and heavily congested. A pilot is required and highly recommended. Additionally, it was reported as recently as 1975 that several wrecks were charted incorrectly and that ships should give them a berth of one-half mile.

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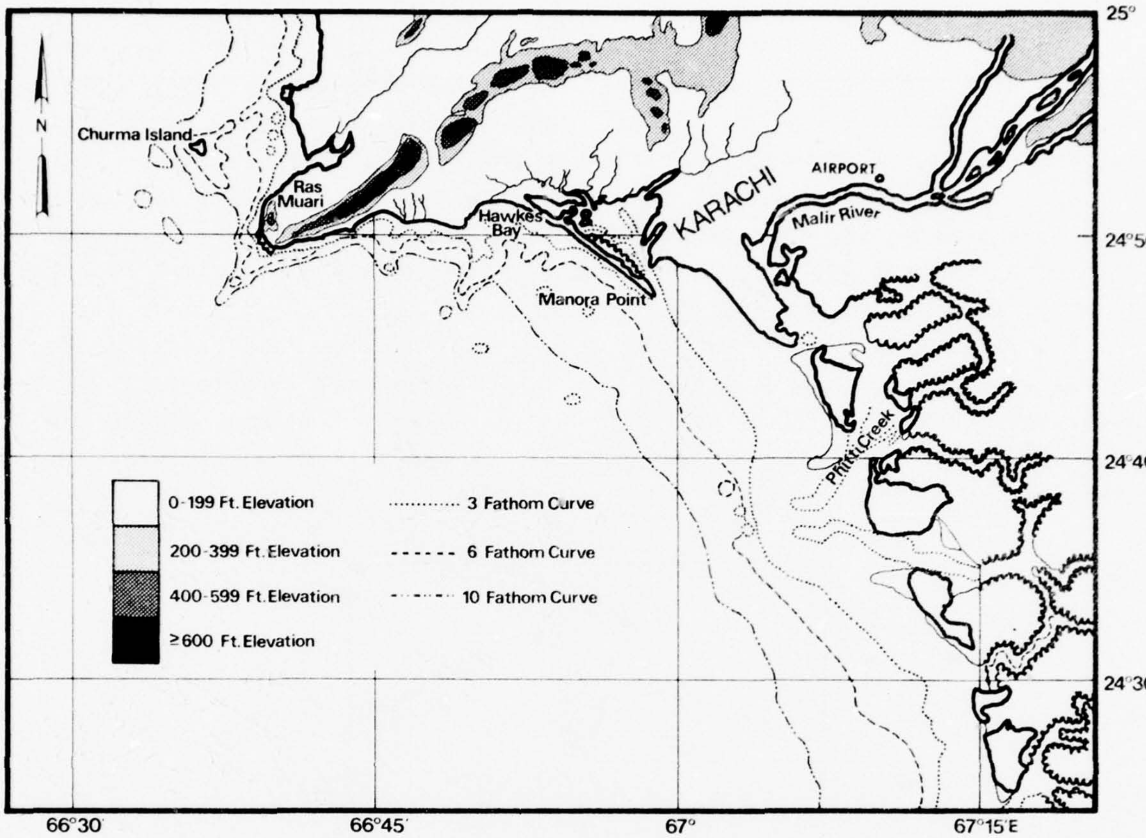

Figure IX-2. Topographical map of the Karachi area.

On incoming tidal currents during the southwest monsoon, a considerable swell rolls into the lower harbor near Manora Point. Dredging is continuously in progress to maintain charted depths, but silting is liable to occur during the southwest monsoon.

Ships up to a maximum length of 600 ft (183 m) can enter Karachi Harbor, and vessels with a draft of up to 25 ft (7.6 m) can enter and leave the harbor any time day or night. During the southwest monsoon, vessels drawing up to 32 ft (9.8 m) are permitted to enter and leave port, but this draft maximum may be increased at the discretion of port authorities. Inasmuch as the dredged channel is liable to silting during the southwest monsoon, the permissible draft must be regulated by the conditions of weather and sea.

KARACHI

The total harbor (Figure IX-3) extends about 3-1/2 n mi (6.5 km) north-northwestward and north-northeastward, and ranges from 250 to 500 yd (229 to 457 m) wide between the 20 ft (6.1 m) depth curves. The lower harbor is that portion from Manora Point to the southern end of East Wharf, about 1-1/2 n mi (2.8 km); its navigable channel is reduced, in general, to about 300 yd (274 m) by the banks extending from each side. The upper harbor extends northward and north-northeastward about 2 n mi (3.7 km) and has a navigable width of 300 to 400 yd (274 to 366 m) for most of its length.

In approaching Karachi from the south, there are no good landmarks while passing the delta of the Indus and land is not generally visible until Manora Point comes into view. This approach is particularly dangerous during the southwest monsoon because continuous haze combined with overcast skies make determination of ship's positions difficult.

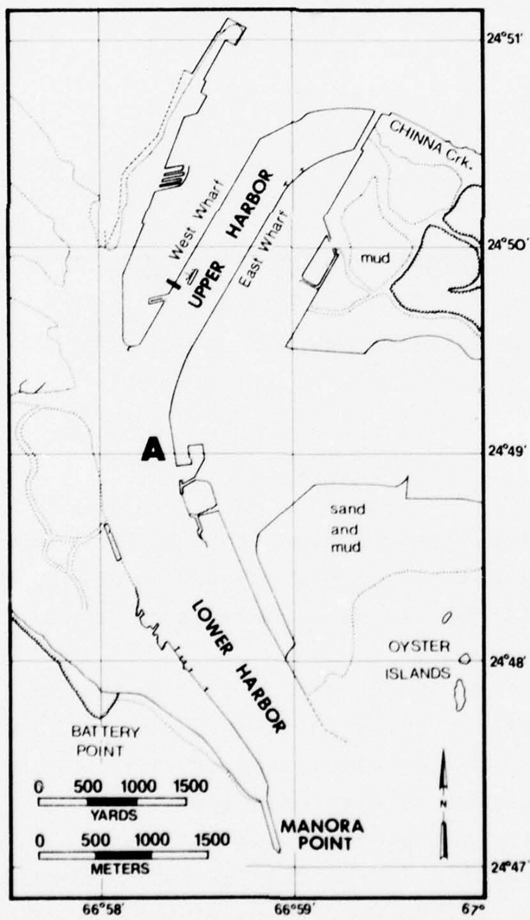

Figure IX-3. Karachi Harbor.

Strong cross currents are experienced during a flooding tide and silting has been very heavy in the channel paralleling the shipyard and naval dockyard. Caution should therefore be exercised during entry and exit because of the rapid silting and flood tide currents.

Getting underway from a Karachi wharf during the southwest monsoon is a problem. Winds up to 20 kt are common, and if a vessel is berthed at East Wharf, the wind sets the ship on the pier. U.S. Navy ships typically have been assigned to wharves 1, 2 or 3 (see A of Figure IX-3), although these would not be as sheltered as the pierside wharves in the upper harbor.

To eliminate some of the congestion at Karachi Harbor, the Karachi Port Trust is planning to build new berthing facilities near Phitti Creek, 13 n mi southeast of Karachi. The plan is to have 10-12 berthing areas by 1982.

2.2 TROPICAL CYCLONES AFFECTING KARACHI

2.2.1 Tropical Cyclone Climatology for Karachi

The majority of those tropical cyclones that pose a threat to Karachi (any tropical cyclone approaching within approximately 180 n mi is considered a "threat") occur during the months June-November. Figure IX-4 gives the monthly frequency distribution of threat situations based on data from 1950-70.[1] In Figure IX-5, these threat tropical cyclones are displayed according to the compass octant from which they approached Karachi; note that approximately 76% approached from the south through east.

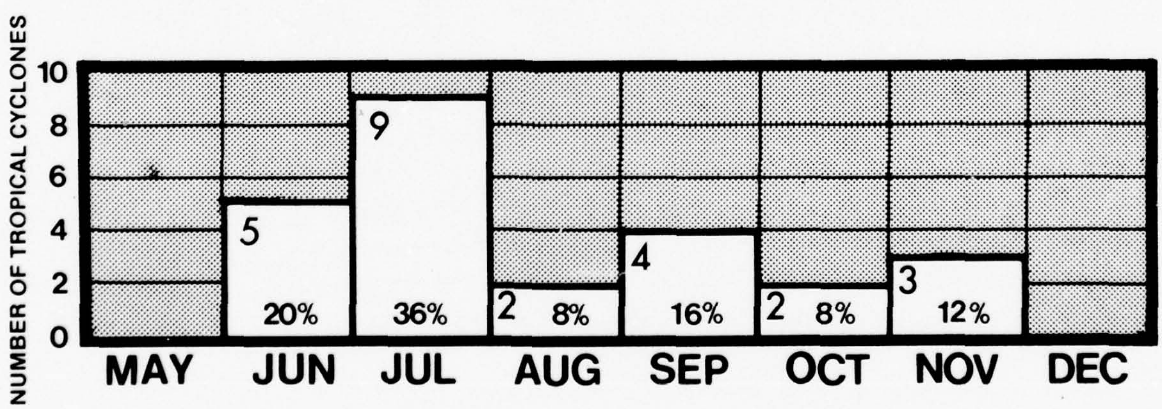

Figure IX-4. Monthly frequency distribution of tropical cyclones passing within approximately 180 n mi of Karachi (data period 1950-70).

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[1]Tropical cyclone data is based on "Tracks of Storms and Depressions in the Bay of Bengal and the Arabian Sea, 1877-1960," published by India Meteorological Department, 1964 and "Supplemental Tracks of Storms/Depressions, 1961-1970," published by India Meteorological Department.

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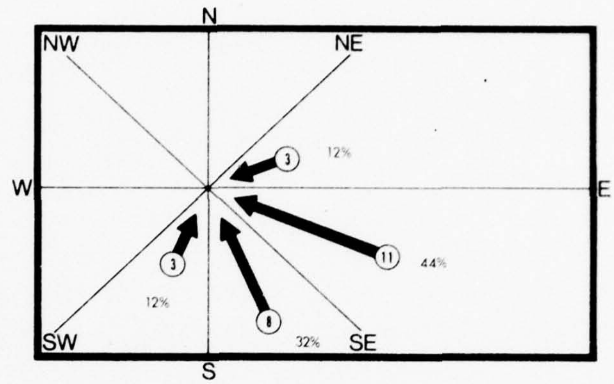

Figure IX-5. Direction of approach to Karachi of the tropical cyclones (1950-70) that passed within approximately 180 n mi of Karachi. Circled numbers indicate the number that approached from each octant. The numbers in ( ) indicate the percentages of the total sample (25) that approached from each octant.

Figures IX-6 through IX-8 show the percentages of tropical cyclones that have passed within approximately 180 n mi of Karachi (these can be interpreted as a probability of threat) for the period June through November. The dashed lines represent approximate approach times to Karachi based on a typical approach speed of 6 to 8 kt. For example, in Figure IX-6 a storm located at 15N, 70E has a 60% probability of passing within 180 n mi of Karachi, and if its speed remains in the 6 to 8 kt range it will reach Karachi in three to four days. Notice that the threat axis shifts from one time period to the next. In June (Figure IX-6), the threat is mostly from the south-southeast. In the July-September period (Figure IX-7), the threat broadens out to the east as tropical cyclones from the Bay of Bengal region affect Karachi. In October and November (Figure IX-8), the threat shifts to the south.

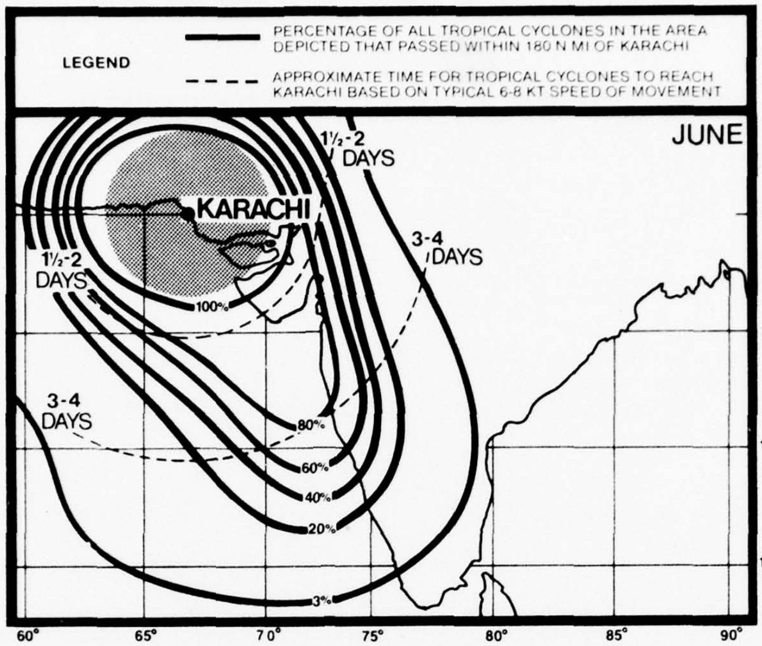

Figure IX-6. Probability that a tropical cyclone will pass within approximately 180 n mi of Karachi (shaded area) in the month of June (based on data from 1950-70).

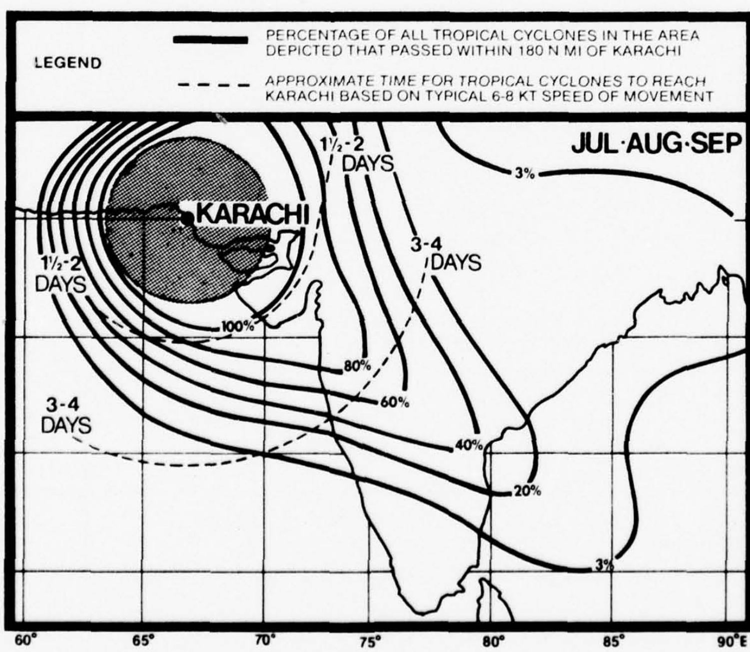

Figure IX-7. Probability that a tropical cyclone will pass within approximately 180 n mi of Karachi (shaded area) in the months of July-August-September (based on data from 1950-70).

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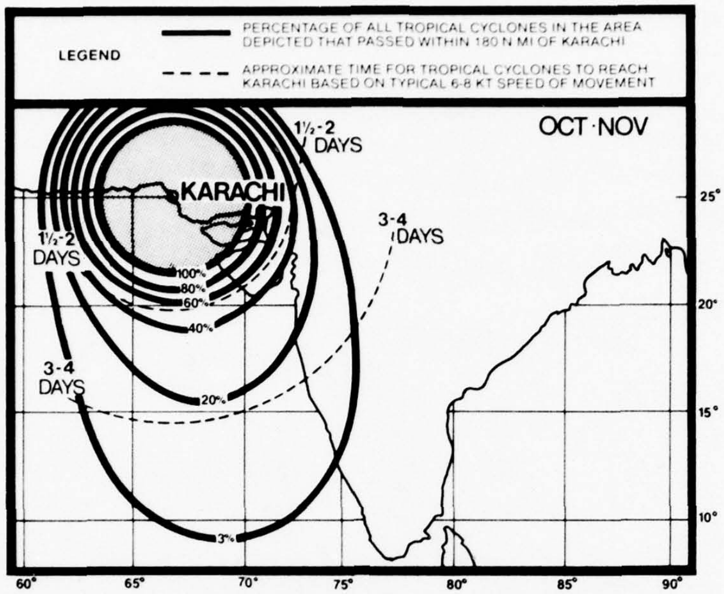

Figure IX-8. Probability that a tropical cyclone will pass within approximately 180 n mi of Karachi (shaded area) in the months of October-November (based on data from 1950-70).

In the 21-year period 1950-70, an average of slightly more than one tropical cyclone a year passed within 180 n mi of Karachi. In Table IX-1, these 25 tropical cyclones are grouped according to their effects on Karachi.[2] Only six tropical cyclones contributed to gale force winds or greater ($\geq$ 34 kt). The highest sustained wind at Karachi that can be attributed to a tropical cyclone in this period was 45 kt from the north-northeast in July 1962 as the tropical cyclone approached from the south-southeast. This is a reflection of the fact that the tropical cyclones affecting Karachi are in fact weakening, whether they are coming from the south or from the east.

Table IX-1. Extent to which tropical cyclones affected Karachi during the period 1950-70.

Number of storms that passed within 180 n mi	25
Number of storms resulting in winds $\geq$ 22 kt at Karachi	17
Number of storms resulting in winds $\geq$ 34 kt at Karachi	6

[2]Wind data is based on hourly wind information from Karachi Airport contributed by the Pakistan Meteorological Department. The data, after being examined and compared with other hourly wind data in the Karachi area, was found to be representative of the winds in Karachi Harbor.

2.2.2 Winds Associated with Tropical Cyclones at Karachi

Figure IX-9 shows the positions of the tropical cyclone track segments (1950-70) when sustained strong winds ≥ 22 kt were first and last recorded at Karachi; the tracks are based on hourly wind information. It is apparent that winds ≥ 22 kt occur when the storms are to the east and south of Karachi. This is consistent with the fact that almost all strong wind directions were from the northeast quarter. This is also evident in Figure IX-10 which shows the tropical cyclone track segments when gale force sustained winds ≥ 34 kt were first and last recorded at Karachi. Notice that one tropical cyclone was 250 n mi to the south and east and still contributed to ≥ 34 kt winds. Also note that the arrow segments are rather small, which is indicative of only a short time period of gale force winds.

Probably the most dangerous threat situation would be in the case of a close passage (within 20 n mi to the east and 40 n mi to the west) of a tropical cyclone approaching from the south and with maximum sustained winds greater than 70 kt. The problem to Karachi would be enhanced by the fact that many of the tropical cyclones in the Arabian Sea are slow-moving (5-9 kt) as compared to western North Pacific tropical cyclones. A close passage of a severe tropical cyclone would contribute to strong winds for an extended period of time, in a region where strong winds are uncommon.

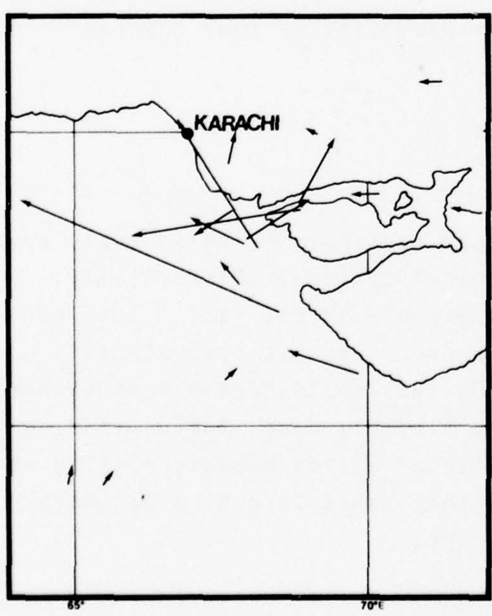

Figure IX-9. Positions of tropical cyclone track segments when winds greater than or equal to 22 kt first and last occurred at Karachi (based on data from 1950-70).

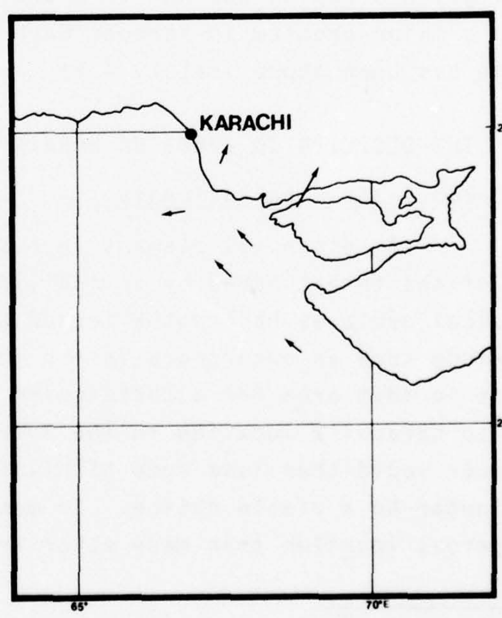

Figure IX-10. Positions of tropical cyclone track segments when winds greater than or equal to 34 kt first and last occurred at Karachi (based on data from 1950-70).

In the summer period (July-September), a number of the tropical cyclones that contributed to strong winds at Karachi were tropical cyclones that originated or developed in the northern Bay of Bengal and traversed India while still maintaining enough of a circulation to contribute strong winds at Karachi. These tropical cyclones, most of which are actually monsoon depressions, have different characteristics as compared to the more typical tropical cyclones. They generally have weak gradients and are more intense at 3000-5000 ft above the surface. Many times squalls occur extending out 150-200 n mi around these depressions. This is not the kind of storm that would be as dangerous as the tropical cyclone coming from the southern section of the Arabian Sea region as is more common in June, October and November.[3]

2.2.3 Wave Action and Storm Surge

Waves are not a problem within the harbor, but the mouth of the harbor and the outer anchorage area can experience up to 25 ft seas under tropical cyclone conditions. In fact the summer monsoon typically brings forth 10-15 ft seas. The sea state should be taken into account when considering evasion from Karachi during the summer period, since the typical 10-15 ft seas will be certainly enhanced by any tropical cyclone to the south (see Para. 4, Chapter 1), even if it is hundreds of miles away.

Storm surge can be defined as the difference in observed water level at a given location during storm and non-storm conditions. Storm surge has *not* been a major problem in Karachi Harbor in the past; the maximum observed storm surge has been approximately 4 ft.

2.3 THE DECISION TO EVADE OR REMAIN IN PORT

2.3.1 Evasion Rationale

An essential element in heavy weather decision-making is early appraisal of the threat posed by an individual tropical cyclone. Historically, tropical cyclones have not affected Karachi severely in the past. This does not preclude such an occurrence in the future, however, because the potential does exist in this area for a threatening situation that could become very dangerous due to Karachi's location in the Arabian Sea. In this case, the commanding officer would then lose some of his flexibility of action because evasion would no longer be a viable option. In many ways, this makes Karachi a far more dangerous location than many other tropical ports.

[3] For a more detailed discussion of the environmental phenomena in the Arabian Sea, refer to "Meteorological Phenomena of the Arabian Sea," Naval Environmental Prediction Research Facility Applications Report 77-01, 1977.

Some rough guidelines that might be of use in decision-making are presented in conjunction with Figure IX-11.

I. An existing tropical cyclone moves into or significant development takes place in area A with forecast movement toward Karachi:

a. Review material condition of ship. A sortie may be desirable 2-4 days hence.

b. Reconsider any maintenance that would render the ship incapable of getting underway within 48 hours.

c. Plot FWC/JTWC, Guam, tropical cyclone warnings.

II. Tropical cyclone moves into or significant development takes place in area B with forecast movement toward Karachi:

a. All units consider possible course of action if sortie should be ordered.

b. If the maximum wind of the tropical cyclone is 70 kt or greater, sortie should begin before tropical cyclone enters area C.

c. Monitor FWC/JTWC tropical cyclone warnings. Be aware of local marine forecasts issued by Pakistan Navy.

III. Tropical cyclone enters area C with forecast movement toward Karachi:

a. Remain in port and prepare for heavy weather.

b. If tropical cyclone rapidly intensifies to 70 kt or greater, sortie only if tropical cyclone is southeast of Karachi. If tropical cyclone is southwest of Karachi, remain in port.

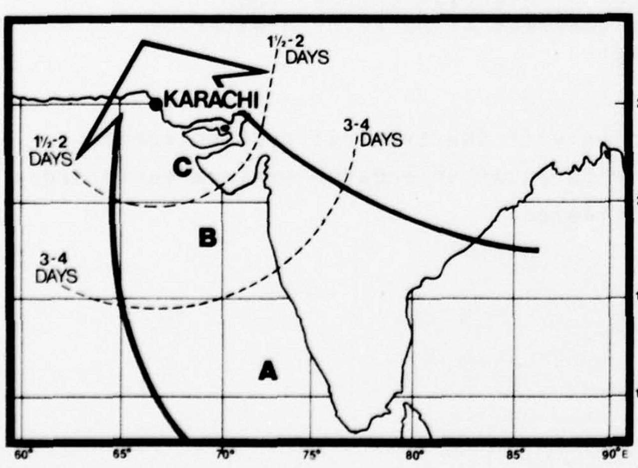

Figure IX-11. Tropical cyclone threat axis for Karachi. Approach times to Karachi are based on typical 6-8 kt forward speeds of movement for tropical cyclones affecting Karachi.

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2.3.2 Remaining in Port

Remaining in Karachi Harbor is the recommended course of action in almost all tropical cyclone threat situations. Historically this has been a safe course of action because recent data indicate that the highest maximum sustained wind attained during the period 1950-70 due to a tropical cyclone was 45 kt. Adequate berthing and mooring facilities are provided inside Karachi Harbor for securing ships safely and doubling up their working lines during bad weather conditions. In addition, if vessels were to part their mooring lines or drift from their positions, services of qualified pilots and powerful tugs would be available to render the required assistance. The Karachi Port Trust could provide assistance to secure ships at wharves and moorings inside the harbor to a reasonable degree of safety.

The following should also be considered during threat situations:

(1) Securing to a pier or buoy should be accomplished before winds reach 25 kt in order to avoid undue difficulty.

(2) The upper harbor is more sheltered than the lower harbor. Typically U.S. Navy vessels are assigned wharves 1, 2 or 3 (near A on Figure IX-3). This area is more exposed than the upper harbor wharves.

(3) Once heavy weather begins, getting underway will be difficult.

(4) Tropical cyclones coming within 180 n mi of Karachi in the past have contributed to strong winds mostly from the northeast quarter.

(5) The bottom holding of Karachi Harbor is variable and ranges from poor to good.

(6) For any ships waiting in the outer anchorage, the recommendation is to get underway.

(7) If crowded conditions prevail in the harbor and the ship is moored due to lack of pierside spaces, the recommendation is to get underway if 50 kt or greater sustained winds are expected.

2.3.3 Evasion at Sea

Evasion at sea is recommended only if the tropical cyclone threat situation indicates passage of a storm with 70 kt or greater maximum sustained wind. The following should also be considered:

(1) A tropical cyclone threat from the south leaves little maneuvering room in the northern Arabian Sea. An early appraisal of the threat is important and evasion should be oriented toward proper avoidance of the danger area. If threatened by a tropical cyclone approaching from the south or southeast, the vessel should head west or southwest.[4] If threatened from the southwest, it should head southeast.

(2) Some shelter is provided to the lee of Churma Island, 1/2 n mi northwest of Ras Muari, for any tropical cyclone passage near or to the east of Karachi.

(3) The Gulf of Oman has rarely ever been affected by a tropical cyclone and should be considered as a viable option if the ship is felt to be "boxed in" in the northern Arabian Sea.

(4) A tropical cyclone threatening from the south to southwest can contribute to high seas (up to 15-20 ft) near the entrance to Karachi Harbor even when the tropical cyclone is 200 n mi away.

(5) Tropical cyclone forward speed of movement, for those tropical cyclones threatening Karachi, is typically 6-8 kt, which is slower than the typical western North Pacific Ocean tropical cyclone. This would allow some additional flexibility in evasion.

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[4] It should be noted that high seas (10-11 ft in the average) are typically found in the northwestern Arabian Sea (10-15N, 55-60E) in the months of June-August. If there is a storm threat during these months from the south or southeast, the Gulf of Oman should be considered as an option.

SECTION X - CONTENTS

X NEW ZEALAND

1. GENERAL

The Dominion of New Zealand consists of three principal islands -- North, South, and Stewart -- lying approximately 1000 miles southeast of Australia and stretching between the 34th and 47th parallels (inset, Figure X-1).

New Zealand has a temperate climate and abundant rainfall. Topography varies from glacier-studded mountains more than 12,000 ft high to active and extinct volcanoes to rolling grasslands.

North Island, on which both the capital city of Wellington and the largest city, Auckland, are located, is approximately 465 miles long and 250 miles wide. It is generally hilly (mountainous in some parts), but only a few peaks rise above 6,000 ft (Figure X-1).

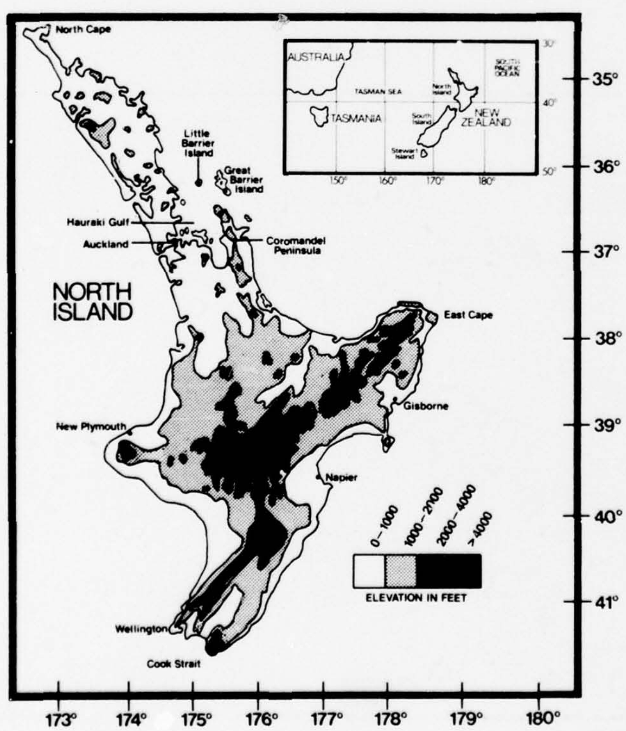

Figure X-1. Locator map, North Island, New Zealand.

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2. AUCKLAND

SUMMARY

Auckland is a suitable port to remain in, or seek refuge in, under tropical cyclone threat conditions as well as during intense extratropical cyclone threat situations that may affect the port. If conditions are such that a ship does not wish to attempt entry to the inner harbor, the Hauraki Gulf will provide shelter for anchoring without restricting opportunities for further movement.

2.1 GEOGRAPHICAL LOCATION AND TOPOGRAPHY

Auckland is located on a narrow neck of land west of the Coromandel Peninsula at the southwest corner of the Hauraki Gulf (Figures X-1 and X-2) and is reached via transit through the Gulf. Hauraki Gulf is protected from most angles by several prominent islands (Little Barrier and Great Barrier Islands) as well as the Coromandel Peninsula and the mainland, all of which can provide steep-to lee anchorages from selected winds. In the southwestern corner of the Gulf, another series of islands (Rangitoto, Motutapu, Waiheke and Ponui) and the Whangaporaoa Peninsula have elevations from 350 to 850 ft and afford shelter to Auckland Harbor and its principal entrance, the Rangitoto Channel (Figure X-2).

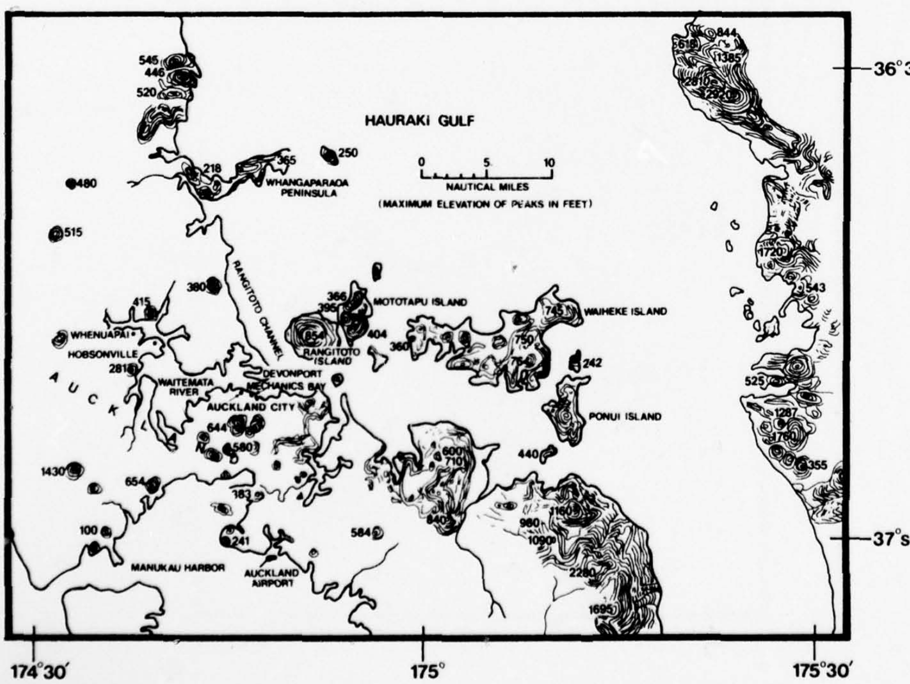

Figure X-2. Topographical features of the Hauraki Gulf/Auckland region.

The city of Auckland is on the south bank of the Waitemata River and the town of Devenport is on the northern shore. The isthmus on which Auckland is situated has a rolling terrain dotted by a number of extinct volcanic cones 300-700 ft high.

2.2 AUCKLAND HARBOR

The lower portion of the Waitemata Estuary at the head of the Hauraki Gulf is one of the most secure and commodious harbors in New Zealand (Figure X-3). It is completely sheltered and protected from strong winds by the outlying chain of islands and peninsulas mentioned above. Although Auckland is a major seaport, traffic is normally light and commercial pierside berthing is usually available. The harbor can be entered at MLWS by vessels up to 30 ft draft, and maximum length for alongside mooring is 825 ft. Depths of berths vary from 25 to 35 ft. Harbor depths range up to 96 ft with good holding ground. The tidal range is from 5.5 to 12 ft. HMNZS Philomel can accommodate about seven destroyer-type ships comfortably. When anchorage is required, a central area between a point due south of the North Head and Harbor Bridge is considered best.

For more detailed information, refer to CINCPACFLT Port Directory and H. O. Publication No. 78.

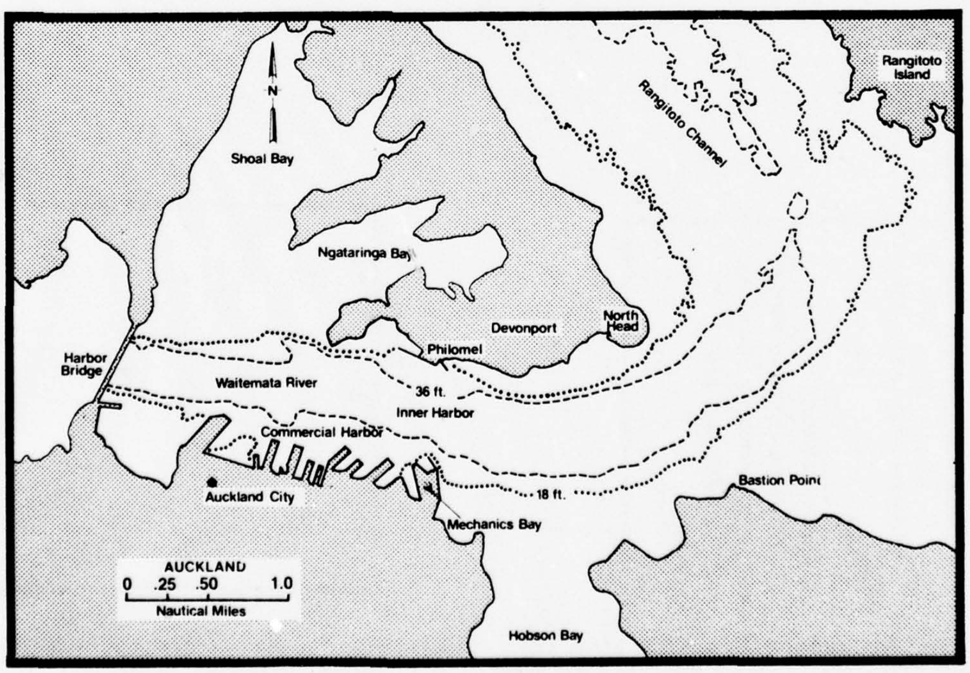

Figure X-3. Auckland Harbor.

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2.3 TROPICAL CYCLONES AFFECTING AUCKLAND HARBOR

2.3.1 Tropical Cyclone Climatology for Auckland

Tropical cyclones that pose a threat to Auckland -- and any tropical cyclone approaching within 180-200 n mi is considered a "threat" -- are usually weakening and fast-moving at the time of passage, with maximum sustained winds typically less than 55 kt at closest point of approach (CPA). The majority of those that pose a threat to Auckland occur during the period January through April.

Figure X-4 is a monthly summary of threat situations based on data from the 44-year period 1932-75. The maximum number of threat situations have occurred in February and March. Figure X-5 depicts these threat tropical cyclones according to the compass octant from which they approached Auckland. Although most tropical cyclones have approached from the NW quarter, 15% have approached from the NE quarter. This fact demonstrates the erratic nature of tropical cyclone tracks in the southwest Pacific, which generally fall into four categories:

Toward the southwest without recurvature	10%
Toward the southeast without recurvature	35%
Toward the southwest, then recurving to east	30%
Toward the southeast, then recurving to west	25%

It should be noted that recurvature, when it does occur, generally but not always occurs far to the north of Auckland. It should also be noted that approximately four to five tropical cyclones can develop in the southwest Pacific each year, and that in some years as many as nine or ten have developed into potentially destructive storms.

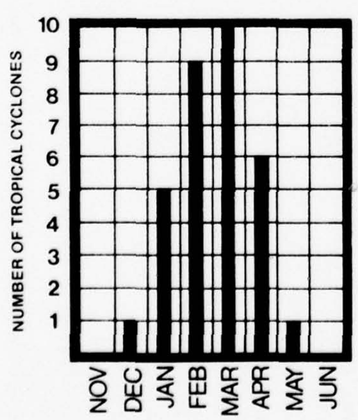

Figure X-4. Frequency distribution of the 32 tropical cyclones that passed within 180-200 n mi of Auckland in the 44 years 1932-75 (New Zealand Meteorological Service, 1976).

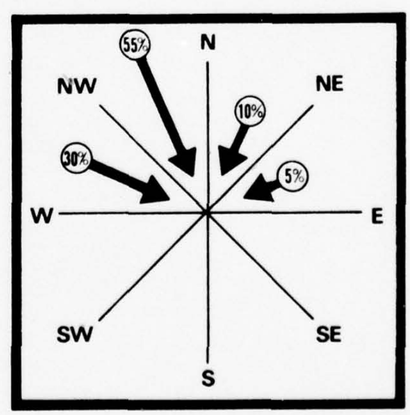

Figure X-5. Direction of approach to Auckland of the tropical cyclones that came within 180-200 n mi of Auckland. Percentages are of the total sample (32 in the years 1932-75) that approached from each octant.

2.3.2 Wind and Seas Due to Tropical Cyclones

Of the 32 tropical cyclones that posed a threat to Auckland during the 44 years 1932-75, approximately one-third contributed to gale force winds (10-min average), but only about four contributed to sustained winds greater than 50 kt (10-min average). However, gusts from 40-60 kt, generally from the NE quarter, were common. Several of these tropical cyclone threat occurrences are described below (from New Zealand Meteorological Service, 1976):

Dates		
1-2 Feb 1936	SSE passing about 30 miles west of Auckland, then curved to SE to pass over center of North Island.	One of the worst storms in New Zealand's history. The worst effects were felt south of Auckland. In Auckland, a few roofs lost, large trees uprooted, 40 small craft badly damaged. Passenger liner stood off (combination of wind, sea and poor visibility).
4 Feb 1940	SSE passing to west of Auckland and over central North Island.	Highest gust at Mechanics Bay (Auckland Harbor) was 63 kt.
20-21 Dec 1952	Moved SW from a position about 400 n mi northwest of Auckland, then recurved to southeast to cross southern North Island.	Strongest winds occurred when cyclone was more than 350 n mi to the northwest of Auckland. Lost intensity rapidly after recurving to southeast.
14-15 Mar 1959	Extremely rapid SE movement from New Caledonia. Recurved to SW to pass north of New Zealand into North Tasman Sea.	Nearest approach to Auckland about 200 n mi, but with extensive area of gales. The worst cyclone experienced in Northland, with highest gust at Kaitaia 96 kt and at Auckland 56 kt.
9 Apr 1968	SSE passing to east of Auckland over Bay of Plenty and Hawkes Bay.	The worst storm in New Zealand's history, but the strongest winds and greatest damage occurred in the Wellington area. Maximum gust at Wellington airport 101 kt with mean wind speed (10-min average) reaching 79 kt. Even stronger winds on exposed hillsides. Relatively little damage at Auckland. Highest gust 60 kt from the southwest after the storm had moved to the southeast of Auckland.

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AUCKLAND

When the center of a tropical cyclone is moving on a southeastward track to the east of Auckland, the wind at Auckland will generally be from the southern quarter during the period of the cyclone's nearest approach to the harbor. The harbor is somewhat protected from the full force of the wind by the surrounding topography. When the storm is still some distance to the north, the winds will be from the northeast, which is the direction with the least topographic protection.

A storm moving southeastward to the west of Auckland will contribute northeast winds when the storm is north and west of the harbor. As the storm passes to the south of Auckland, the topography will provide more shelter from the northwesterly and westerly winds.

Possibly the most dangerous situation would be the close passage of a tropical cyclone between 15 n mi to the west and 25 n mi to the east. If the tropical cyclone was intense (rare at this latitude), severe conditions such as 80-90 kt gusts at the harbor from the northeast quarter could be expected. Strong winds could be experienced from the southwesterly quarter, but these would generally be more steady and affect the harbor less than the northeasterlies.

Most tropical cyclones approaching the latitude of northernmost New Zealand are undergoing transformation. They become extratropical in character and sometimes the area of gale force winds expands. Therefore, gales may occur in Auckland even though the cyclone center is some 300-400 n mi away, and the winds may not necessarily increase as the center approaches. They may even decrease as the center loses intensity or begins to be absorbed in an oncoming trough of low pressure in the westerlies.

The sea state under strong wind conditions is seldom such that it affects the movement of ships. It would not exceed 5 ft within the harbor, and 8 ft could be expected with 70 kt winds in Rangitoto Channel. The only consideration is whether a pilot can board a vessel in Rangitoto Channel, and 8 ft seas would be the maximum allowing boarding.

The waters of the Hauraki Gulf are sheltered by Great Barrier Island, and the sea states are always much less than in the open sea off the northeast coast of North Island. The worst conditions arise in northeast winds, but providing a ship has normal maneuverability, there would be no circumstances in which the Hauraki Gulf could not be considered a safe haven (Chief of Naval Staff, RNZN, 1976). Good anchorage is obtainable in any part of the Gulf.

Storm surge is not considered a problem. Under the most adverse conditions the surge does not exceed 2 ft due to wind, plus a further foot per every 34 mb that the barometric pressure is depressed below 1015 mb. The highest surge has never exceeded 4 ft.

2.4 THE DECISION TO EVADE OR REMAIN IN PORT

2.4.1 Remaining in Port

Remaining in Auckland Harbor, or seeking refuge therein, under tropical cyclone threat conditions is the recommended course of action. If conditions are such that a ship does not wish to attempt entry to the harbor, the Hauraki Gulf will provide shelter for anchoring without restricting opportunities for further movement.

Provided a ship has reasonable maneuverability, there is no restriction on movement due to wind or seas. (Passenger liners have been berthed without difficulty in 70-kt gusts.) Wind is a greater consideration than sea state. In very strong easterly winds, the turn to starboard at the inner end of Rangitoto Channel can be a limiting factor for unhandy vessels, if full tug power is not available. The only berth not used under the worst easterly wind conditions, due to the combined effects of tide and sea, is the Eastern Tide Deflector. Alongside berths have never been vacated under any storm conditions.

Ships in midstream, off the commercial wharves, generally remain anchored under most storm conditions. Extra cable and power on the engines is often used. However, if the port is congested and ships are close together, or if the master so desires, ships may be dispatched to a sea anchorage in the Hauraki Gulf.

There is no typhoon plan or heavy weather plan for Auckland Harbor, as there is little cause to restrict movement. In any event, the actions to be taken to meet unusual circumstances are under the day-to-day control of the Harbormaster. Similarly, during times of Tsunami warning, the Harbormaster may order ships to put to sea.

Figure X-6 shows the tropical cyclone threat axis for Auckland from December through May. The following timetable incorporating Figure X-6 provides guidance for correctly assessing the threat posed by an approaching tropical cyclone:

I. An existing tropical cyclone moves into, or potential development occurs in, Area A with forecast movement toward Auckland:

a. Review material condition of ship.

b. Reconsider all maintenance activities scheduled to exceed 24 hours.

c. Plot FWC Guam warnings. Be aware of local warnings provided by Auckland weather office. Note: Tropical cyclone warnings for storms north of 25°S are issued by Fiji Meteorological Service; for storms south of 25°S, they are issued by the New Zealand National Weather Forecasting Center in Wellington.

II. Tropical cyclone enters Area B with forecast movement toward Auckland:

a. Reconsider all maintenance activities scheduled to exceed 12 hours.

b. Prepare ship for heavy weather and move to secure berth or anchorage. Note: gales could begin for storms 300-400 n mi away.

c. Plot FWC Guam warnings. Be aware of local warnings.

III. Tropical cyclone enters Area C with forecast movement toward Auckland:

a. Ensure sufficient power available to counter high winds and seas by steaming to anchor (see Para. 5, Chapter I).

b. Monitor FWC Guam and local warnings.

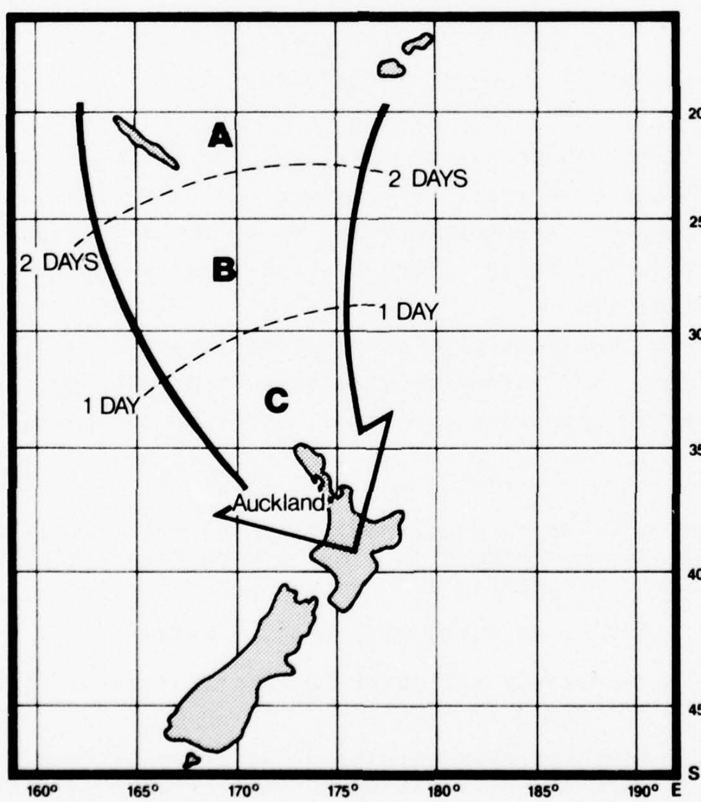


Figure X-6. Tropical cyclone threat axis for Auckland. Approach times are based on typical speeds of movement for tropical cyclones affecting Auckland.

2.4.2 Evasion at Sea

Evasion at sea is not the recommended course of action. Even though the Auckland Harbor area has never been truly tested by a very severe tropical cyclone, conditions outside the harbor and Gulf would be much more severe if a ship evaded without many days of lead time. The erratic nature of the tropical cyclones in this area of the world, combined with forward speeds of movement of up to 30-35 kt, could lead to a destructive encounter. It should be remembered that under strong wind conditions, the seas outside the Hauraki Gulf would be much worse than the seas within.

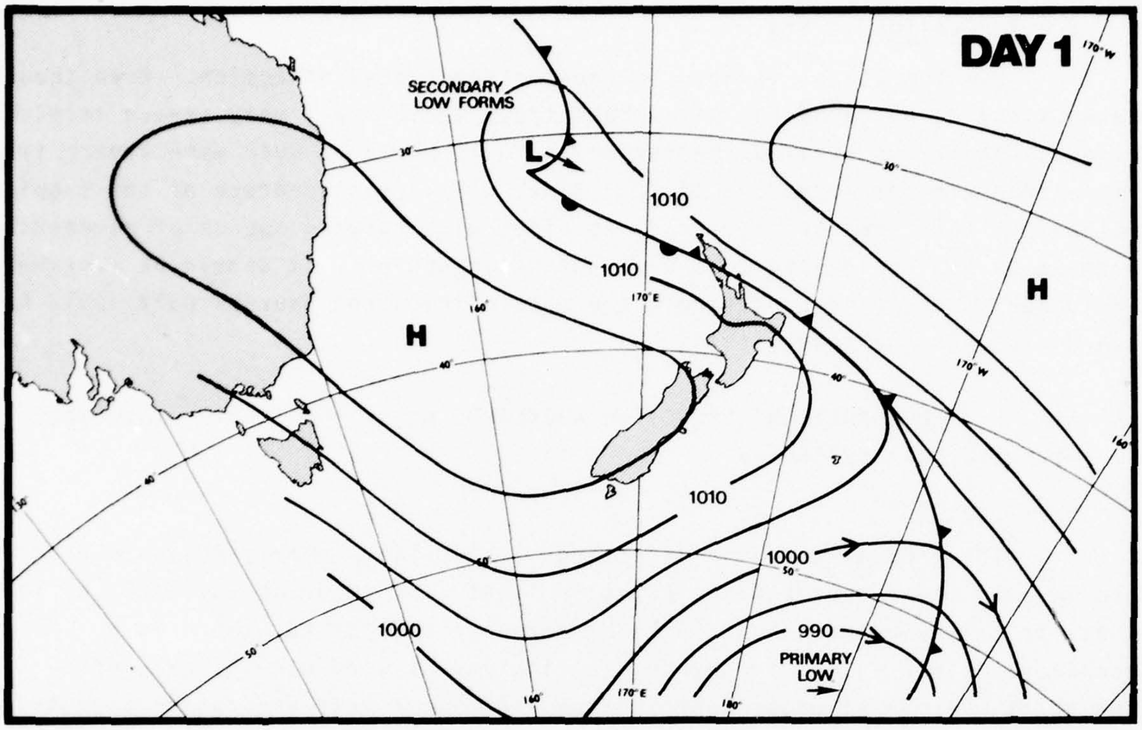
2.5 STRONG WIND CONDITIONS AFFECTING AUCKLAND (other than those associated with tropical cyclones)

2.5.1 General

The predominant wind directions at Auckland, nearly 40%, are from W to SW. In the harbor region, calms or light airs occur about 15-20% of the time. If only winds of about 15 kt or more are considered, there is a secondary maximum in the frequency distribution of wind directions - NE to E. Wind gusts over 33 kt occur approximately 50 days a year and can be expected to be greater than 50 kt only two or three days each year. The highest gust that has been recorded in the harbor region was 67 kt (WSW) in September 1972. The strong winds, especially those from the northeast quarter, are usually associated with either tropical cyclones or winter extratropical storms passing near the harbor.

2.5.2 Strong Winds Affecting Auckland During Winter

During the winter season frontal passages with strong winds can be frequent, but some of the strongest wind conditions are those associated with a storm developing to the northwest. These storms develop on the front associated with a low which passes eastward well to the south of New Zealand. These developing lows intensify quickly and can move rapidly into the New Zealand area. Simultaneously a region of high pressure moves into the area between the two lows, often resulting in a decrease in the speed of movement of the storm. This type of weather pattern, shown schematically in Figure X-7, may occur every few weeks in some years, and be almost completely absent in others.



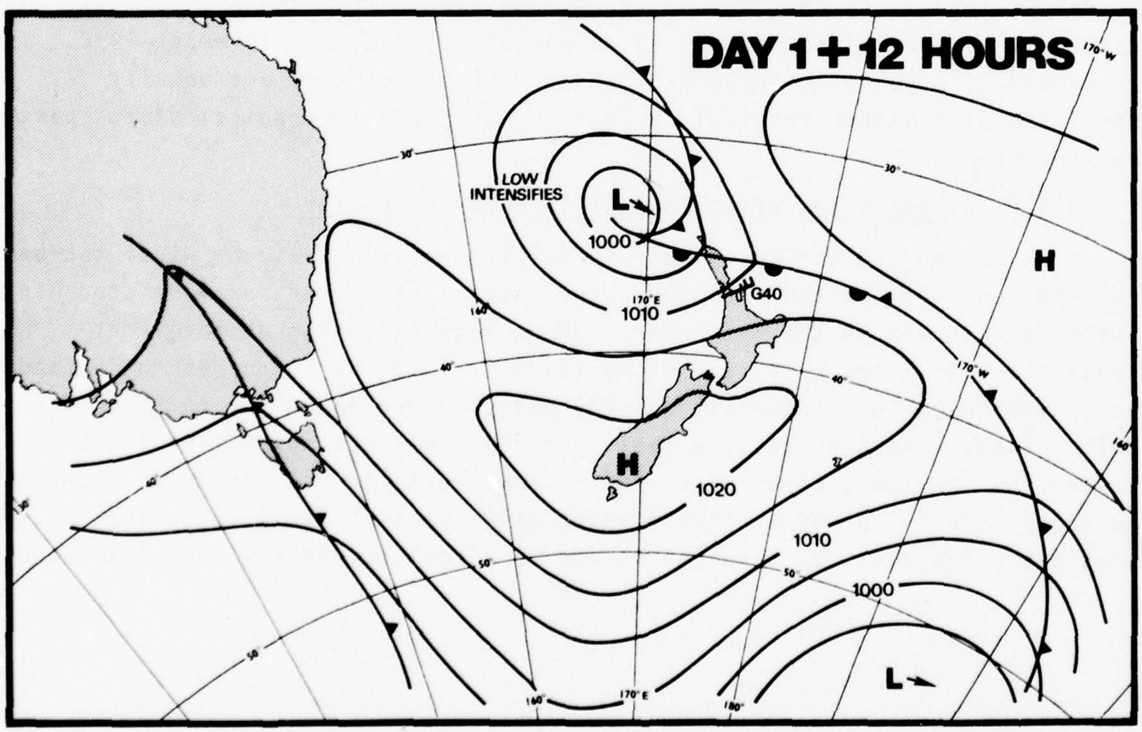
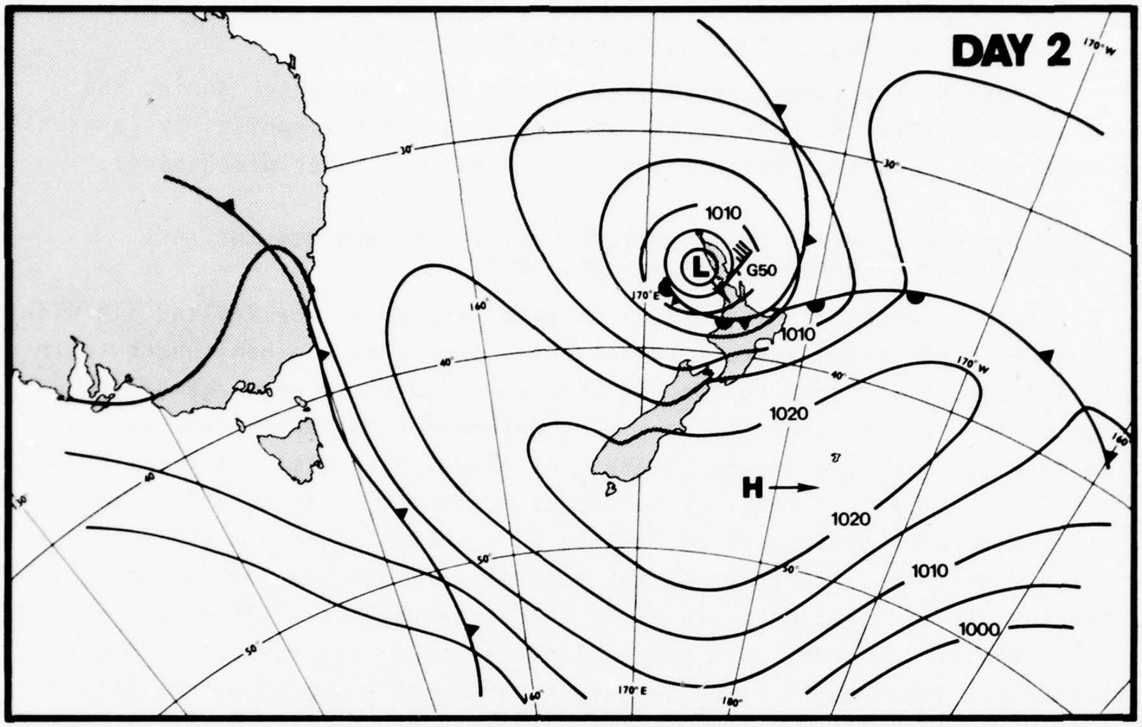


Figure X-7. Synoptic sequence of events associated with a typical type of strong wind condition affecting Auckland Harbor. This event occurs approximately once every 4-6 weeks throughout the May-September period. Wind barb values are in kt and relate to 10-minute sustained winds.



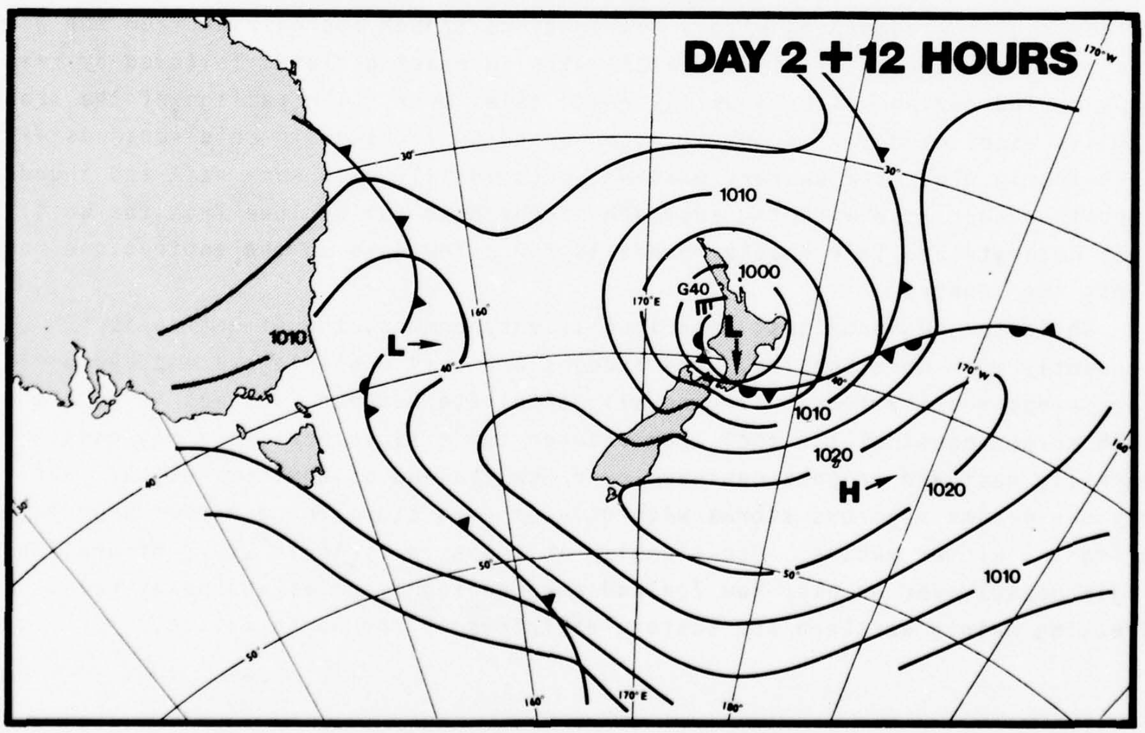


Figure X-7 (Continued).

2.5.3 Strong Winds Affecting Auckland During Summer

Most of the strong winds that affect Auckland Harbor during the summer are associated with tropical cyclones or are extratropical cyclones that have previously been tropical cyclones (see Para. 2.3.2 for discussion).

3. SOME GENERAL COMMENTS ON THE METEOROLOGY OF THE NEW ZEALAND AREA (New Zealand Meteorological Service, 1977)

Situated between 34°S and 47°S, the main islands of New Zealand lie within the broad belt of strong westerly winds which encircles the hemisphere south of about latitude 35°S. Just to the north is the high-pressure ridge of the subtropics from which barometric pressure decreases southwards over New Zealand to the deep low-pressure trough located, on annual mean maps, near latitude 70°S.

The weather pattern from day to day is dominated by a succession of anticyclones, separated by troughs of low pressure, which pass more or less regularly from west to east across the Australia-Tasman Sea-New Zealand area and beyond. In this region there is no semipermanent anticyclone such as those found in similar latitudes over the Indian Ocean and eastern Pacific Ocean, respectively. The troughs normally have a northwest to southeast orientation and are associated with deep depressions centered far to the south. A typical weather sequence commences with a low-pressure trough approaching from the west. Freshening northwesterly winds prevail with increasing clouds followed by rain for a period during which winds may reach gale force. The passage of the trough with its associated cold front is accompanied by a change to cold southwesterly or southerly winds and showery weather, occasionally with some hail and thunder. Barometers then rise with the approach of the next anticyclone from the west. Winds moderate and fair weather prevails for a few days as the anticyclone moves across the country.

While the sequence just described is very common, the situation is frequently much more complex. The troughs are very unstable systems where depressions readily form. They usually originate between 25°S and 40°S to the north or northwest of the cool area between two anticyclones, and may pass, generally eastward or southeastward over New Zealand at any time of the year. They can become vigorous storms with gale or even storm force winds, especially during the winter months. Occasionally in summer a cyclonic storm of tropical origin passes over or near New Zealand accompanied by gales and heavy rain, affecting mainly northern and eastern districts of the North Island.

The anticyclones vary in size, intensity and rate of movement. Their centers, on the average, follow a track across the North Island but individual centers may pass either north or south of the country, the more northerly tracks being favored in spring and the southerly tracks in autumn. The interval of time between the successive troughs of low pressure passing over the country between the anticyclones is very variable. On a seasonal basis, only about one season in two experiences a fairly regular progression of anticyclones and troughs of low pressure. When this occurs the interval between troughs of low pressure is usually between five and eleven days, with a marked preference for eight or ten days. There is no apparent seasonal variation througnout the year.

Other main factors which influence the climate of New Zealand are its position in the midst of a vast ocean, which ensures that the climate is predominantly maritime and windy; and the shape and topography of the country itself, which profoundly affect winds in coastal waters.

Winds. Winds from a westerly quarter prevail in all seasons with a general tendency to increase in strength from north to south. However, considerable local modifications to the general air flow occur during its passage across the mountainous terrain. Approaching the main ranges, the flow from the west turns towards the northeast and on descending on the eastern side swings towards the southeast. This results in an increased number of southwesterlies in Westland and a predominance of northwesterlies in inland districts of Otago and Canterbury, where strong gales from this quarter occur at times in the late spring and summer. Daytime sea breezes usually extend from the coast inland for 30 km (48 n mi) or more during periods of settled weather in summer. On the Canterbury coast the wind comes most frequently from the northeast, partly because there is a persistent sea breeze from this quarter, but south of Dunedin southwesterlies predominate. Cook Strait, the only substantial gap in the main mountain chain, acts as a natural funnel for the air flow and is a particularly windy locality afflicted by gales from the southeast as well as the northwest.

This "funnel" effect is also in evidence about Foveaux Strait. North of Taranaki the general air flow is more from the southwest, and there is a noticeable reduction of windiness in the summer.

Gales over the open sea are most frequent in the winter months (10-15%), but in the summer months the frequency is only about 5%.

Seas. Rough seas are common at all times of the year, especially southward of the parallel of 40°S. During gales, very rough seas are a feature of Cook and Foveaux Straits.

Swell is also a feature of the waters around New Zealand. Heavy swells occur throughout the year 10-15% of the time and during the southern winter this figure increases to 30-40%, especially over the ocean to the east.

REFERENCES

Chief of Naval Staff (RNZN), 1976: Personal communication dated 29 April 1976.

New Zealand Meteorological Service, 1976: Personal communication dated 30 June 1976

New Zealand Meteorological Service, 1977: Personal communication dated 18 February 1977.

SECTION XI - CONTENTS

XI AUSTRALIA

Australia, the smallest continent and the barrier between the Indian and Pacific Oceans, is located between Indonesia and Antarctica. The driest of all continents, approximately half its total area consists of desert regions. Population centers are on the coast, and large expanses of the immense arid basin and plateau regions remain uninhabited.

Australia is a Commonwealth of six states (see Figure XI-1) -- Northern Territory, Queensland, New South Wales, Victoria, South Australia, and Western Australia -- each with contrasting climates.

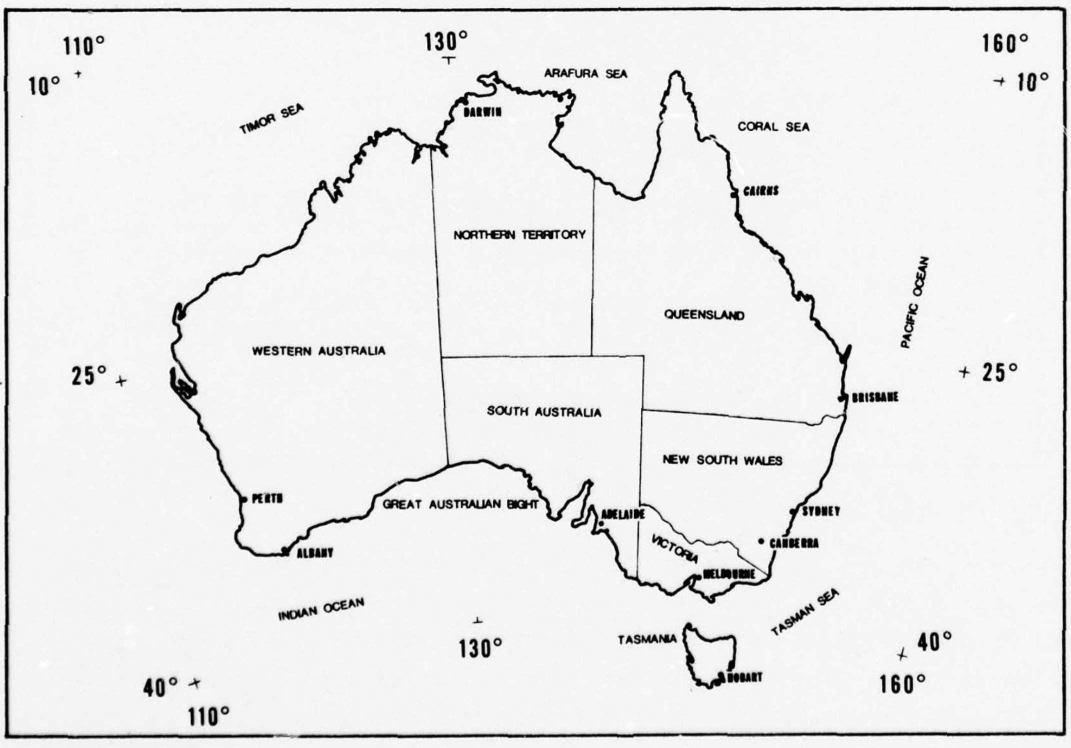


Figure XI-1. States and major cities of the Commonwealth of Australia.

2. FREMANTLE (INCLUDING COCKBURN SOUND)

SUMMARY

The Fremantle area provides safe shelter in the inner harbor or in Cockburn Sound from tropical and extratropical cyclones. Aircraft carriers anchoring in Gage Roads would be more vulnerable to strong winds and seas associated with intense tropical and extratropical cyclones. These conclusions are based on the following:

1. Tropical cyclones passing near Fremantle will be weakening and, based on history, will generally contribute to less than 40 kt sustained winds (10-min average).

2. The strongest winds typically occur during the winter season of June through October, with several occurrences of sustained winds (10-min average) of 40-50 kt or greater throughout the winter season.

3. Garden Island to the west of Cockburn Sound significantly reduces westerly winds and seas in Cockburn Sound, and the inner harbor is well protected from winds and seas.

4. The blue clay anchor holding ground is excellent in Cockburn Sound and is considered good in Gage Roads.

5. The Harbormaster expresses confidence in the harbor when he states that "No ship has ever left the harbor due to approaching bad weather."

6. The present channel from Gage Roads to Cockburn Sound might be too restrictive for some aircraft carriers; therefore, they would tend to anchor in Gage Roads which is potentially more susceptible to an intense tropical cyclone or very intense extratropical cyclone.

2.1 GEOGRAPHICAL LOCATION

Perth, the capital city of Western Australia, is situated 12 miles inland on the Swan River. To the east, the Darling Range forms a plateau region generally 1000-2000 ft in elevation (Figure XI-2).

The city and port of Fremantle, the principal west coast shipping facility, is located at the mouth of the Swan River.

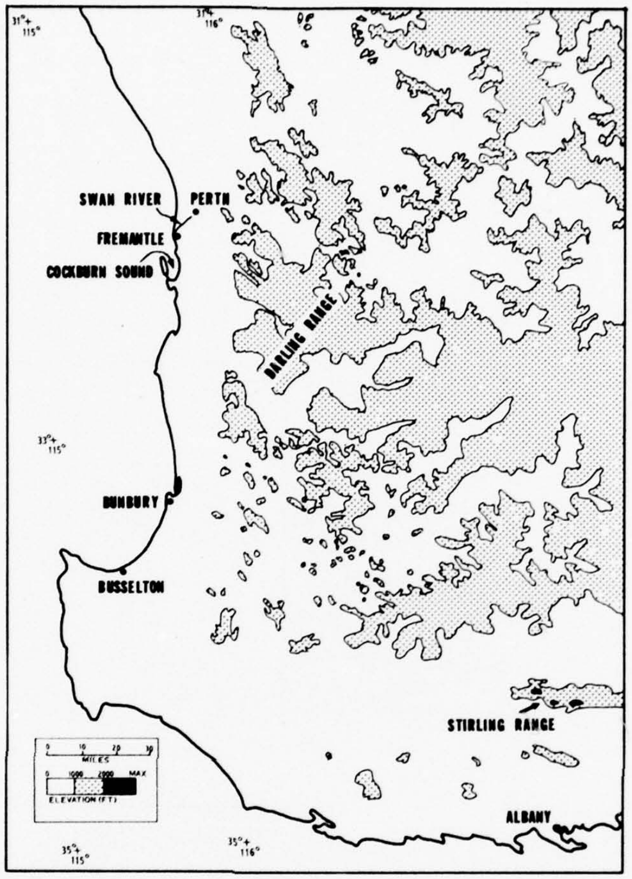


Figure XI-2. Southwest Australia.

2.2 FREMANTLE HARBOR

Cockburn Sound is the most sheltered of the three anchorage areas (Gage Roads, Owen Anchorage and Cockburn Sound) in Fremantle's expansive outer harbor (Figure XI-3). The inner harbor extends a short distance up the Swan River to the northeast.

The northern end of Cockburn Sound is approximately five miles south of the entrance to the Fremantle inner harbor. Transit into Cockburn Sound must be made from the north via single channels through two very shoal banks, Success Bank and Parmelia Bank, which separate the three anchorage areas respectively from the north (total channel length - 3 3/4 miles). The channels are in-line, 492 ft wide and 45 ft deep. Cockburn Sound, a spacious anchorage area approximately four miles wide by eight miles long, is situated between Garden Island to the west and the mainland to the east and south (Figure XI-4).

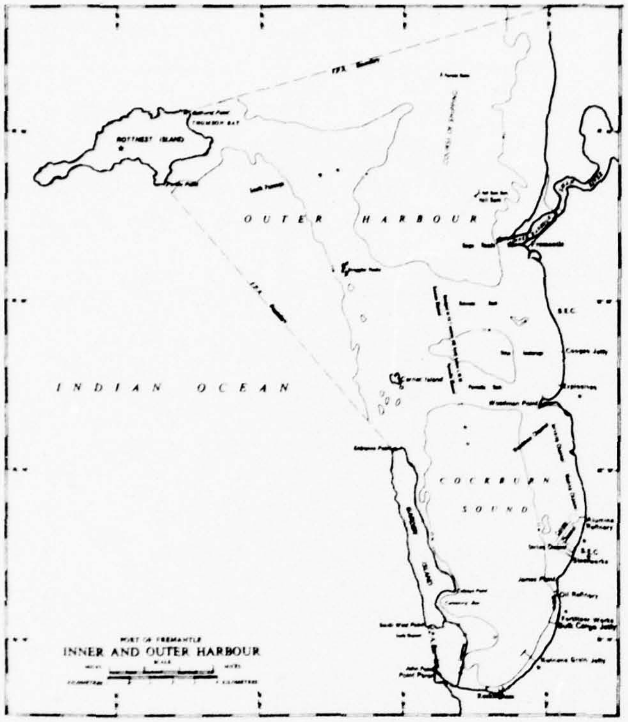


Figure XI-3. Port of Fremantle.

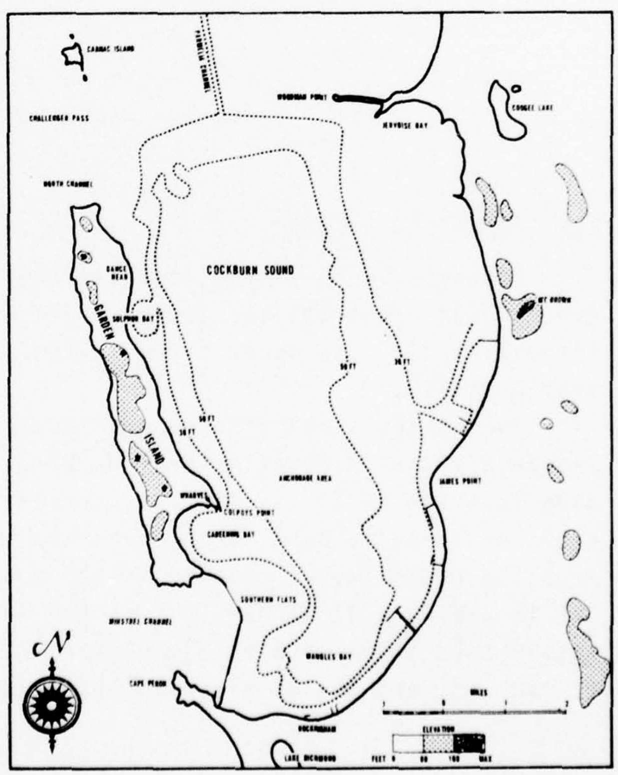


Figure XI-4. Cockburn Sound.

Garden Island protects the U-shaped embayment from the west. Its irregular terrain is broken by several hills roughly 165 ft in height. A causeway at the southwestern end of the sound connects Garden Island with Peron Point across a very shoal strand of sandy and rocky reefs; only small boats can pass west. This area is under staged development to provide additional naval port facilities.[1] It is also expected that by 1978, a number of 30,000-ton mooring buoys will be located just to the east of Garden Island.

As an anchorage area, Cockburn Sound is quite versatile and affords secure anchorages at almost all points. Most of the area provides depths ranging from 30 to 72 ft. It is well protected from most winds and the holding ground is generally a stiff blue clay that provides an excellent setting.

For more detailed information, refer to CINCPACFLT Port Directory and H. O. Publication No. 74.

2.3 TROPICAL CYCLONES AFFECTING FREMANTLE HARBOR

2.3.1 Tropical Cyclone Climatology for Fremantle Harbor

Tropical cyclones that pose a threat to Fremantle -- and any tropical cyclone approaching within approximately 180-200 n mi is considered a "threat" -- are usually weakening at the time of passage. The maximum sustained winds of the tropical cyclones are typically less than 55 kt at the closest point of approach (CPA). The majority of those that pose a threat to Fremantle occur during the period January through April.

Figure XI-5 is a December-May monthly summary of threat situations based on data for the 28 years, 1949-76. The maximum number of threat situations have occurred in February and March. Figure XI-6 depicts these threat tropical cyclones according to the compass octant from which they approached Fremantle; their tracks are shown in Figure XI-7. Figure XI-8 shows the percentages of tropical cyclones that have passed within 180-200 n mi of Fremantle during the months of December through April; these data can be interpreted as indicating probability of threat. The dashed lines in Figure XI-8 represent approximate approach times to Fremantle based on typical speeds of tropical cyclones affecting this port -- for example, a tropical cyclone located at 24°S, 111°E has a 50% probability of passing within 180-200 n mi of Fremantle and will typically reach it in approximately 1½-2 days.

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[1]HMAS STIRLING will be a support facility when completed. It will provide shore support and intermediate level maintenance to submarines and surface ships.

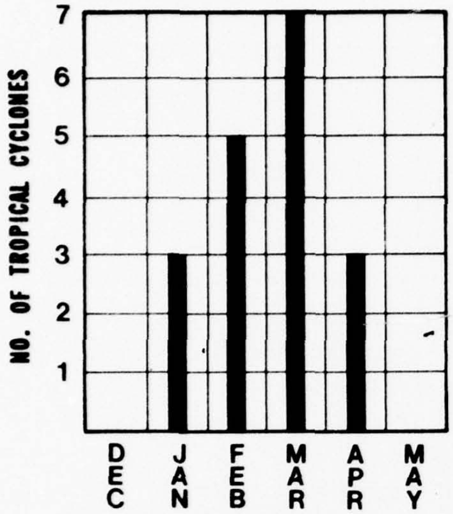

Figure XI-5. Frequency distribution of the number of tropical cyclones (18) that passed within approximately 180-200 n mi of Fremantle during the period 1949-76.

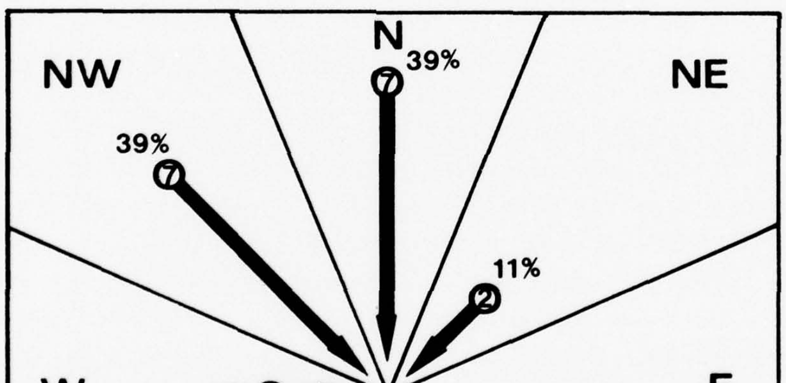

Figure XI-6. Direction of approach to Fremantle of tropical cyclones (1949-76) that passed within approximately 180-200 n mi of Fremantle. Circled numbers indicate the number that approached from each octant. Percentages indicate the percentage of the total sample of 18 that approached from each octant.

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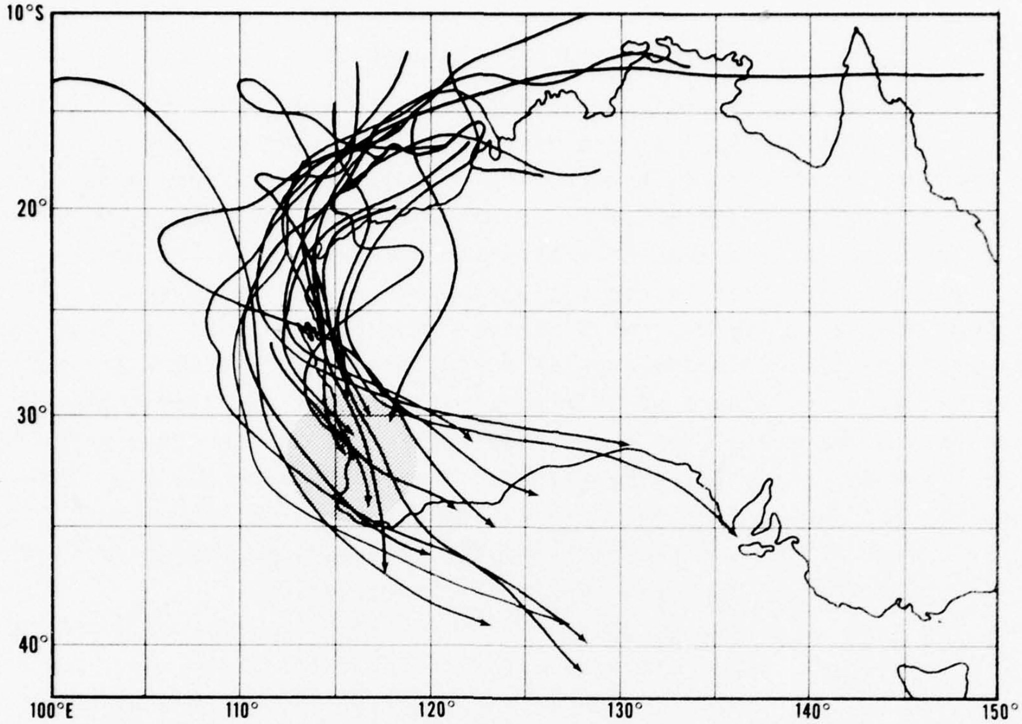

Figure XI-7. Tracks of tropical cyclones (1949-76) that passed within approximately 180-200 n mi of Fremantle.

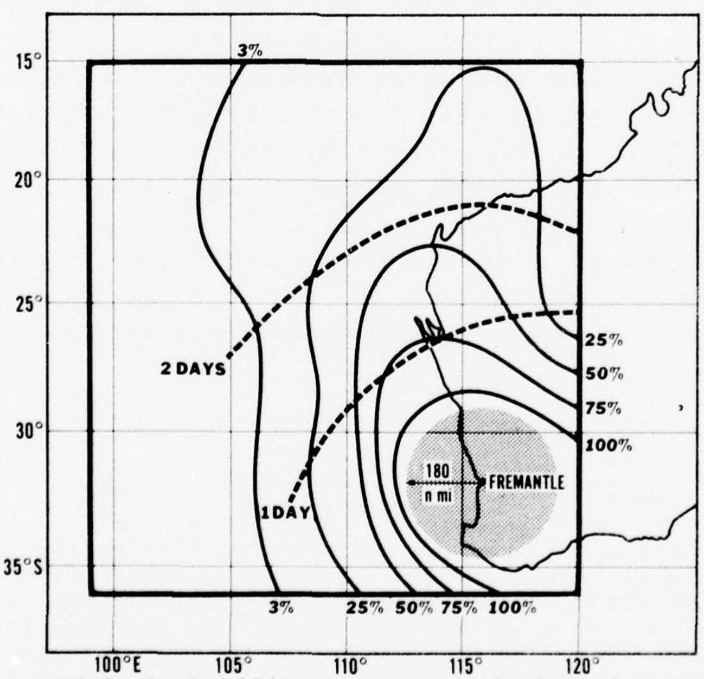

Figure XI-8. Probability that a tropical cyclone will pass within approximately 180-200 n mi of Fremantle for the months December through April. The broken lines indicate approximate approach times to Fremantle based on typical speeds of movement of tropical cyclones affecting Fremantle. (Based on data from 1949-76).

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2.3.2 Wind and Seas Due to Tropical Cyclones

Of the 18 tropical cyclones that posed a threat to Fremantle during the 28-year period 1949-76, only two or three contributed to sustained winds (10-min average) of gale force or greater.[2] However, gusts from 40-60 kt and generally from the NW or NE were common from these tropical cyclones.

The tropical cyclones that threaten the Fremantle area are usually tropical cyclones that have become extratropical and have weakened. Some of these storms move very rapidly, with forward movement at 20-30 kt at CPA to Fremantle, so the time of occurrence of strong winds associated with the storms is brief. However, it should be kept in mind that as these storms become extratropical in character, the area of gale force winds sometimes expands. Gales therefore may occur in Fremantle with the center some 300 n mi away, and the winds may not necessarily increase as the storm center approaches. They may even decrease as the cyclone center loses intensity or begins to be absorbed in an oncoming trough of low pressure in the westerlies.

The most dangerous situation for the Fremantle area would be a close (10-20 n mi) passage just to the west. In addition, the storm would have to be intense at CPA (> 60 kt maximum wind at this latitude could be considered intense). The rarity of occurrence of such a combination of close passage and intensity leads to the conclusion that the Fremantle area is a good tropical cyclone haven. This is particularly true in the sheltered areas of Cockburn Sound (the wharves of Colpoy's Point or anchorages to the east of Garden Island, for example) or in the inner harbor. The only exception would be for a carrier anchoring in Gage Roads, an area more exposed to the north and west. Gage Roads could also experience 10-15 ft seas, whereas Cockburn Sound would never have seas greater than 9 ft under the worst possible conditions. It should also be noted that while Gage Roads might be having 10-15 ft seas, the open sea to the west could be experiencing 20-30 ft seas.

Storm surge does not appear to be a problem in the Fremantle area.

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[2] One recent example was Tropical Cyclone Vida (March, 1975), which passed some 150-180 n mi to the southwest of Fremantle and contributed approximately 40 kt (NE) sustained winds (10-min average) and a peak gust of approximately 75 kt (NNE). It should be noted that sustained wind measured in the Australian region is a value relating a 10-min average rather than a 1-min average more commonly used in the Northern Hemisphere. The latter could be 25-30% larger. Also note that the wind records examined were from the Perth City anemometer and the Fremantle area winds could be from 30% to 50% higher for certain strong wind conditions.

2.4 THE DECISION TO EVADE OR REMAIN IN PORT

2.4.1 Remaining in Port

Remaining in Fremantle is the recommended course of action for all ships except those aircraft carriers anchoring in Gage Roads.[3] The Cockburn Sound area, as well as the security of the inner harbor, provide excellent shelter from the effects of tropical cyclones affecting Fremantle. Additional improvements are expected to the Cockburn Sound area to further enhance this recommendation.

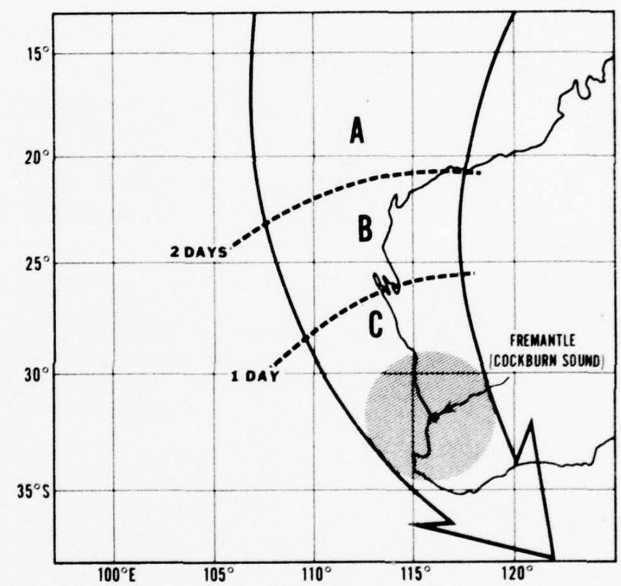

Figure XI-9. Tropical cyclone threat axis for Fremantle. Approach times are based on typical speeds of movement for tropical cyclones affecting Fremantle Harbor.

Figure XI-9 shows the tropical cyclone threat axis for Fremantle from January through April. The following timetable incorporating Figure XI-9 provides guidance for assessing the threat posed by an approaching tropical cyclone:

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[3]Aircraft carriers with their large sail areas would find the narrow channel leading to the protected area of Cockburn Sound hazardous to transit in moderate or high winds.

I. Existing tropical cyclone moves into, or potential development occurs in, Area A with forecast movement toward Fremantle:

a. Review material condition of ship.

b. Reconsider all maintenance activities scheduled to exceed 24 hours.

c. Plot FWC Guam warnings. Be aware of local tropical cyclone warnings issued by Tropical Cyclone Warning Center at Perth.[4]

d. Carriers begin planning course of action should sortie be ordered.

II. Tropical cyclone enters Area B with forecast movement toward Fremantle:

a. Reconsider all maintenance activities scheduled to exceed 12 hours.

b. Prepare ship for heavy weather. Move to secure anchorages or wharves in Cockburn Sound, or to inner harbor.

c. Plot FWC Guam warnings. Be aware of local warnings.

d. If intense tropical cyclone is forecast to pass within 200 n mi and have maximum winds > 60 kt at CPA, recommend carriers take evasive action to WSW if anchored in Gage Roads.

III. Tropical cyclone enters Area C with forecast movement toward Fremantle:

a. Ensure sufficient power available to counter high winds and seas by steaming to anchor (see Para. 5, Chapter I).

b. Monitor FWC Guam and local warnings.

2.4.2 Evasion at Sea

Evasion at sea is not the recommended course of action. The only exception would be for carriers anchored in Gage Roads and with the expected arrival of an intense tropical cyclone (> 60 kt maximum wind at CPA). Such an occurrence is rare in the Fremantle area, but as is the case with many ports, the Fremantle area has never been truly tested in recent times by the close passage of a severe tropical cyclone.

The evasion route to the WSW is short and direct with following sea and wind for almost all tropical cyclone threat situations (see timetable in Para. 2.4.1).

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[4]The weather office in Perth has been extremely helpful to U.S. Navy ships in the past. If any serious weather problem does arise, direct contact with the weather office is recommended.

2.5 STRONG WIND CONDITIONS AFFECTING FREMANTLE (other than associated with tropical cyclones)

2.5.1 General

The winds at Fremantle are generally easterly, E to SE prevailing in summer and E to NE in winter. This pattern is interrupted in summer by regular late morning or afternoon sea breezes which produce moderate to fresh SW winds. Although the mean values of the wind speed are highest in the summer due to the sea breeze, the strongest winds are produced in winter (May-October) by extra-tropical storms developing or moving in close proximity to Fremantle.

2.5.2 Strong Winds Affecting Fremantle During Summer

Some local criteria for strong surface winds (> 30 kt) during the summer season are as follows:

(1) An anticyclone above 1024 mb is located in the near vicinity of southwest Australia.

(2) The winds at 2000-3000 ft are strong.

(3) The pressure falls or rises rapidly.

(4) The pressure gradient between the following points is at the value given or greater:

Geraldton - Naturaliste	8 mb
Kalgoorlie - 112°E	14 mb
Perth - 106°E	14 mb

(5) A pressure fall of 4 mb in three hours occurs at Cape Leeuwin.

(6) The pressure at Perth is 1030 mb or higher.

(7) A strong high pressure center to the west of Australia could enhance the sea breeze significantly.[5]

A typical four- to seven-day sequence of summer mean sea level (MSL) charts is shown schematically in Figure XI-10. The first day of the sequence usually contributes the strongest winds in the Fremantle area.

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[5]A strong SW sea breeze could severely hamper small boat loading and unloading of a carrier at anchor in Gage Roads.

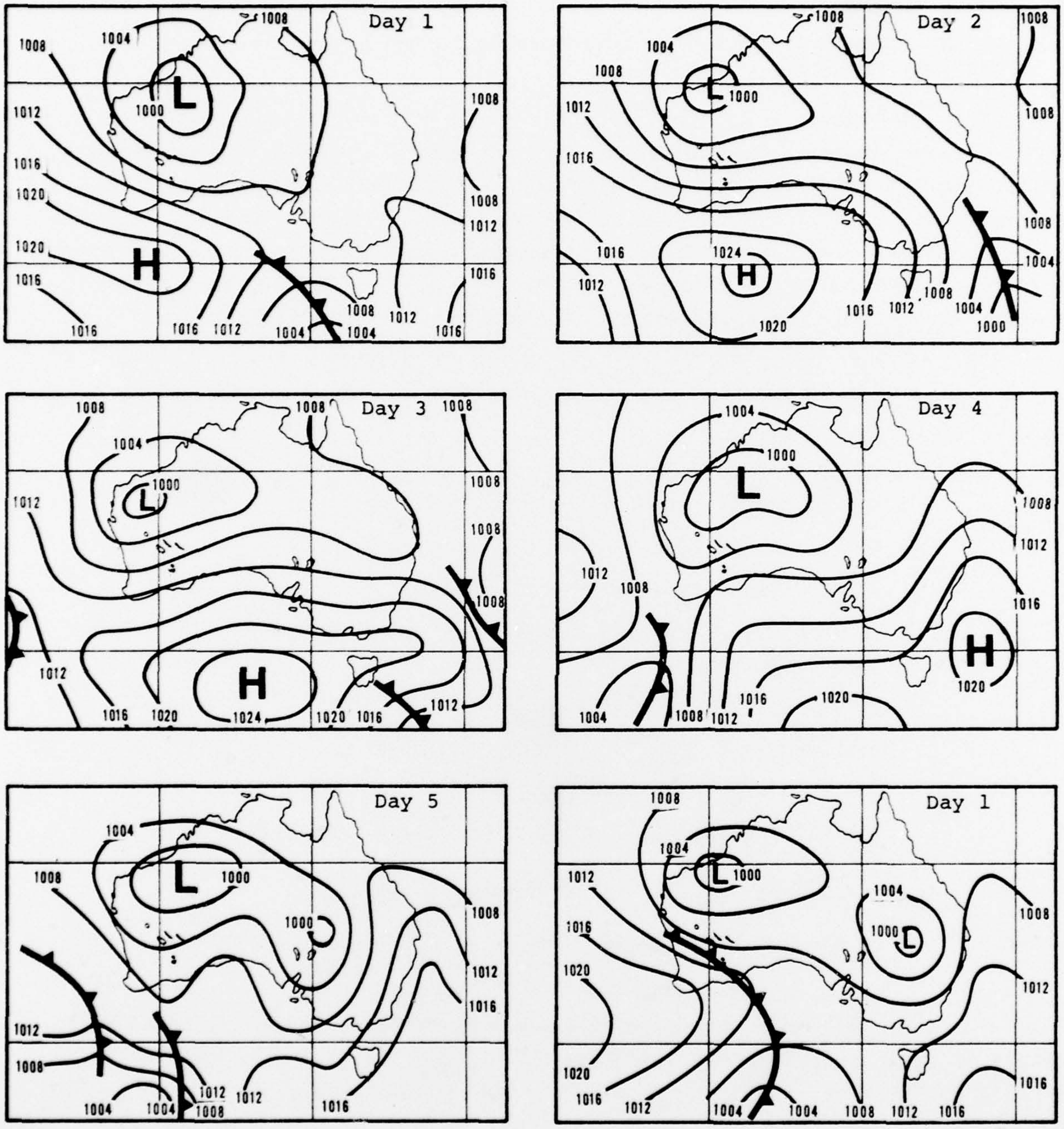

Figure XI-10. A typical 4-7 day sequence of weather during the summer that would contribute to strong winds at Fremantle. On Day 1, strong ESE winds (25-30 kt with gusts to 40 kt) could be expected from 0300 to 1200 local time.

2.5.3 Strong Winds Affecting Fremantle During Winter

The highest winds that affect Fremantle occur during the winter (May through October), with gusts exceeding 60 kt occurring approximately four times a year in the Fremantle area. These very strong winds are generally from the WNW to WSW and they tend to be associated with intense mid-latitude developing storms or intense storms passing in close proximity.

Some local criteria for strong surface winds (> 30 kt) during the winter season are as follows:

(1) The pressure north of 35°S in the vicinity of southwest Australia is 1000 mb or less.

(2) A high pressure area of 1024 mb or greater is moving into the area. A stationary high pressure area of 1030 mb is located in the area.

(3) A pressure fall of 4 mb in three hours occurs at Cape Leeuwin.

(4) See Para. 2.5.2, item (4).

The most common synoptic situation (every five to six days during the winter) that contributes to strong winds at Fremantle during the May-October period is depicted in Figure XI-11a.[6] Also depicted (Figure XI-11b) is the situation that occurs once every month or so and contributes to very strong winds at Fremantle. Although variations of these two patterns do occur, they are the basic synoptic situations which generally bring strong winds during the winter.

It should be noted that the shelter afforded by Garden Island protects ships either at anchor just to the east of Garden Island or tied up at Colpoy's Point when strong westerly winds affect Fremantle.

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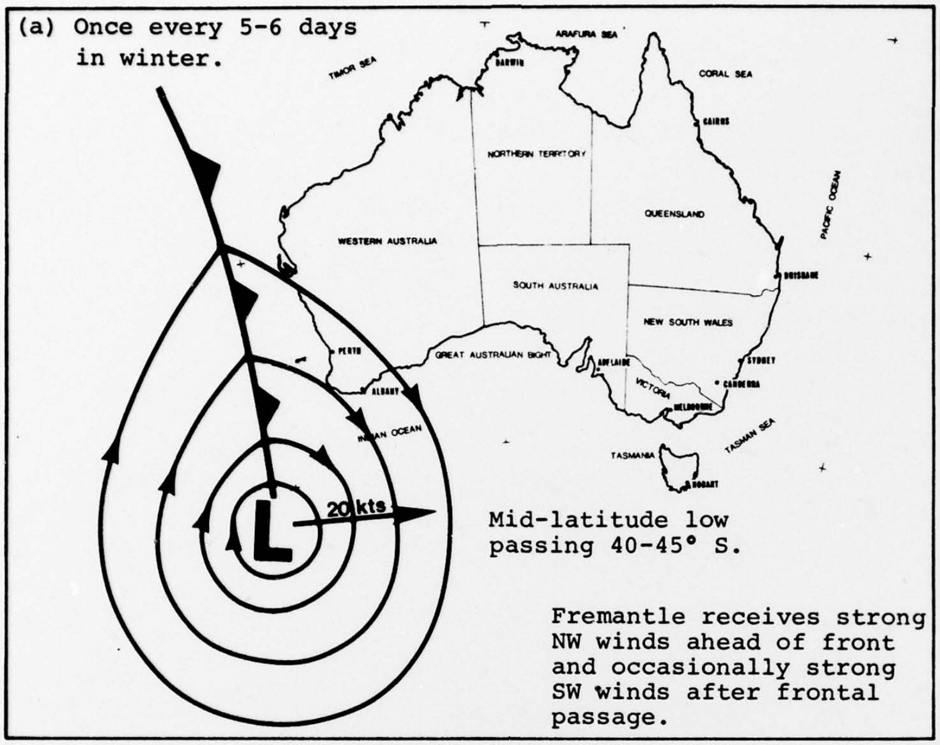
[6] The USS CORAL SEA (CV-43) was anchored in Gage Roads for approximately one week in June 1974 and experienced several frontal passages such as in Figure XI-11a. The CORAL SEA encountered 30-kt winds before and after passages for about 18 hours and incurred approximately 8 ft seas. These conditions hampered small boat loading and unloading during the visit.



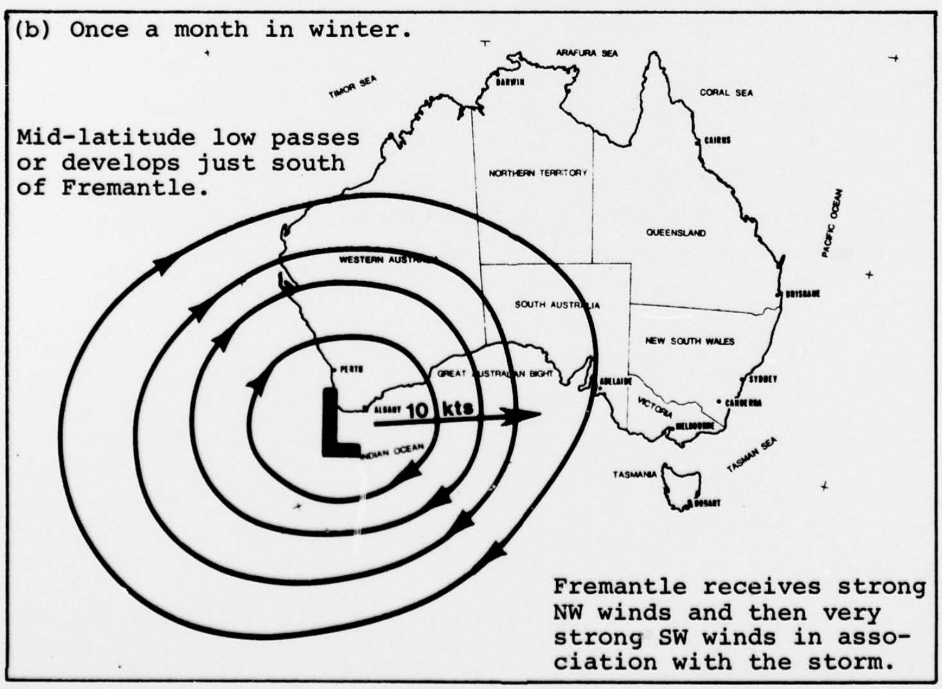


Figure XI-11. Typical synoptic events contributing to strong winds at Fremantle during the winter.

3. SOME METEOROLOGICAL INFORMATION FOR THE FREMANTLE HARBOR AREA[7]

3.1 GAGE ROADS

3.1.1 Anchorages

In the summer season, October to April, safe and convenient anchorage will be found in Gage Roads, in depths of from 14.6 m to 16.5 m (48 ft to 54 ft), fine sand; a good berth is about one mile WSW of the entrance to the inner harbor. In winter, vessels should anchor about 1/2 mile farther W or NW, preferably in the red sector of Woodman Point Light (32° 08' S, 115° 46' E). The bottom inshore is rocky. Most vessels now enter the inner harbor.

3.1.2 Precautions for Vessels During Winter Months

The following precautions should be observed by vessels at anchor in Gage Roads during the winter months when gales generally commence from N and rapidly shift W with a falling barometer:

(1) The starboard anchor should be the first anchor let go.

(2) With northerly winds and a falling barometer, a good lookout should be kept for bad weather. The port anchor must be always ready, and cables clear to bare ends.

(3) With a falling barometer, when the wind shifts W of N, a vessel should let go the port anchor, giving a proportionate quantity of cable to the starboard anchor.

(4) On the wind shifting to NW, with barometer still falling, the wind will be approaching its maximum and may reach gale force. Sufficient cable should be given to the vessel to ensure her riding safely.

(5) When the wind shifts to W and WSW, it generally increases; care should be taken that the ship does not ride with too short a scope on the port cable.

(6) As the wind shifts S, with a rising barometer and weather moderating, the port anchor should be weighed to prevent turns being taken in the hawse in the event of the wind going round E-about, as it generally does, and returning to the NE quarter. The starboard anchor should then be hove in to about 110 m (360 ft) in readiness for further bad weather. On signs of the approach of further bad weather, the precautions described above should be repeated.

(7) Should the wind after backing to SW, veer to W and NW, the gale is not over, but will probably blow harder than before, the barometer keeping below 1016 mb.

The barometer is a good indicator of the weather, as a general rule rising with S and falling with N winds. It invariably gives several hours notice of the approach of bad weather.

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7 The Australian Pilot, Vol. 5, No. 3, 1975.

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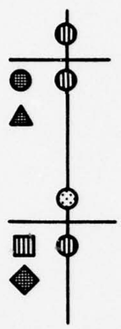
3.1.3 Storm Signals

The following special storm signals are shown at the signal station on the Harbor Authority office[8] when winds exceeding 19 kt are forecast:

STORM AND STRONG WIND WARNING SIGNALS



GALE WARNING: WIND OVER 33 KNOTS

BY DAY: ONE BLACK SPHERE OVER A BLACK CONE-POINT UPPERMOST

BY NIGHT: TWO RED LIGHTS IN A VERTICAL LINE 2M APART

STRONG WIND WARNING: WIND FROM 20-33 KNOTS

BY DAY: A RED SQUARE OVER A DIAMOND SHAPE

BY NIGHT: A GREEN LIGHT OVER A RED LIGHT 2M APART

The day signals only of the above warnings are also exhibited from the front channel light post on the eastern end of the new town jetty berths at Thomson Bay, Rottnest

COLOR REFERENCE FOR ABOVE SIGNALS

GREEN

RED

BLACK

All vessels in the inner and outer harbors must take necessary precautions when these storm signals are shown. Such warnings will be passed by telephone to vessels berthed alongside in the inner harbor.

3.1.4 Weather Forecasts

In addition to the regular radio weather forecasts, the latest information for vessels in port may be obtained from the Perth Office of the Bureau of Meteorology listed in the Perth Telephone Directory in the Commonwealth Section under "Science, Department of."

3.1.5 Mean Sea Level

The mean sea level is lowered during the summer months when breezes off the land are general, and raised during the winter months when N to W winds are frequent. Prior to and during winter gales, the water may rise to 1.5 m (5 ft), and on rare occasions to 1.8 m (6 ft), above chart datum.

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[8]The Harbor Authority office is clearly visible to all ships in the vicinity of the port and commands an overall view of the inner and outer harbors (latitude 32°03'20"S, longitude 115°44'23"E).

3.2 OWEN ANCHORAGE

3.2.1 Woodman Point

The SE part of Owen Anchorage, under Woodman Point (Figure XI-4), is preferable during the summer, when strong breezes prevail from S and W.

In the center of Owen Achorage there are depths of from 12.8 to 14.6 m (42 to 48 ft), but there are several shallow patches in the anchorage.

The NE part of Owen Anchorage, known as Beagle Anchorage, affords good shelter for small vessels of light draft in comparatively smooth water, even during the winter months.

3.2.2 Parmelia Bank

Parmelia Bank, with depths of less than 5.5 m (18 ft), extends 5 miles W from Woodman Point and separates Owen Anchorage from Cockburn Sound. Woodman Spit, the inner part of Parmelia Bank, extends 1/2 mile W from the coast 3 cables NE of Woodman Point, and dries; foul ground extends 3/4 mile NNW from the W end of Woodman Spit. Shoal areas, with depths of from 1.5 m to 1.8 m (5 to 6 ft) over them, and on which the sea breaks heavily with a westerly swell, lie on Parmelia Bank 1 1/2 and 2 1/4 miles WNW of Woodman Point (32° 08' S, 115° 45' E).

3.3 COCKBURN SOUND

3.3.1 East Side of Cockburn Sound

Between Woodman Point (32° 08' S, 115° 45' E) and James Point, 5 miles S, the coast forms a bight; Jervoise Bay is in the north part.

Although protected from NW, a heavy swell rolls into Jervoise Bay, through Challenger Pass and North Channel, during W gales, and with SW winds a short, heavy sea sets in; landing is impracticable during these winds because of the surf on the beach.

3.3.2 Southern Flats

Southern Flats, on which there are rocky patches that are nearly awash, extend NE from Cape Peron, and thence across to the S extremity of Garden Island; the flats are steep-to on their N, E and SE sides. With a heavy W or SW swell the sea breaks heavily on the flats.

3.3.3 Minstrel Channel

Minstrel Channel, leading to Cockburn Sound from seaward, lies between the S end of Garden Island and John Point (32°16'S, 115°41'E); it is barred by Southern Flats, described above, and there are many patches of from 3.7 m to 5.5 m (12 to 18 ft) in the entrance from seaward, which lies immediately N of John Ledge. There is a depth of about 2.7 m (9 ft) over the bar, which may be crossed, in fine weather and with local knowledge, by small vessels; in SW gales the sea breaks throughout the passage.

3.3.4 Middle Ground, Current

A strong current sets NE across Challenger Pass, between Middle Ground and Sea Reef, during SW winds, and S during NW or N winds.

SECTION XII - CONTENTS

XII DIEGO GARCIA

SUMMARY

Diego Garcia is not a typhoon haven. The surrounding topography is low and does not provide an extensive wind break. Expected winds of 60 kt or greater justify a sortie to the north of all ships in the lagoon. With expected winds around 35-40 kt, sortie is not recommended. Small harbor craft can be moored at existing pier structures and larger ships can be anchored in the lee anchorage. In the past 30 years, the island has not been seriously affected by a severe tropical cyclone even though it is threatened about once a year. The maximum sustained wind associated with a tropical cyclone in the past 30 years at Diego Garcia has been approximately 40 kt.

1. GEOGRAPHIC LOCATION AND GENERAL DESCRIPTION

Diego Garcia, the southernmost island in the Chagos Archipelago and a part of the British Indian Ocean Territory, is centrally located in the Indian Ocean (Figure XII-1). It is a narrow atoll 39 miles long that nearly encloses a lagoon 13 miles long and up to 6 miles wide (Figure XII-2). Depths in the lagoon range from 60 to 100 ft; numerous coral heads extend toward the surface and form hazards to navigation. Shallow reefs surround the island on the ocean side as well as within the lagoon. The new channel and anchorage area (shown in Figure XII-2) are dredged to 45 feet (mean low water springs), and the old turning basin can also be used if depth is sufficient for ship type.

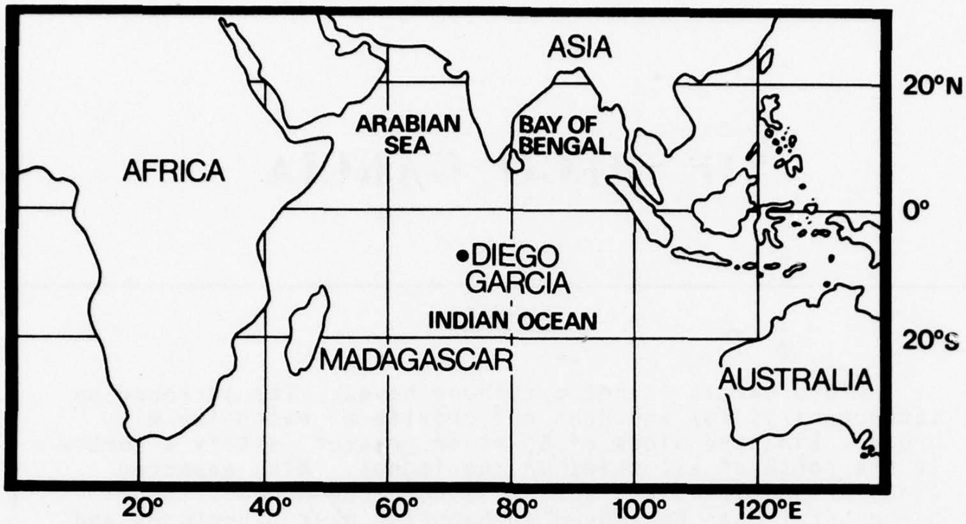

Figure XII-1. Locator map.

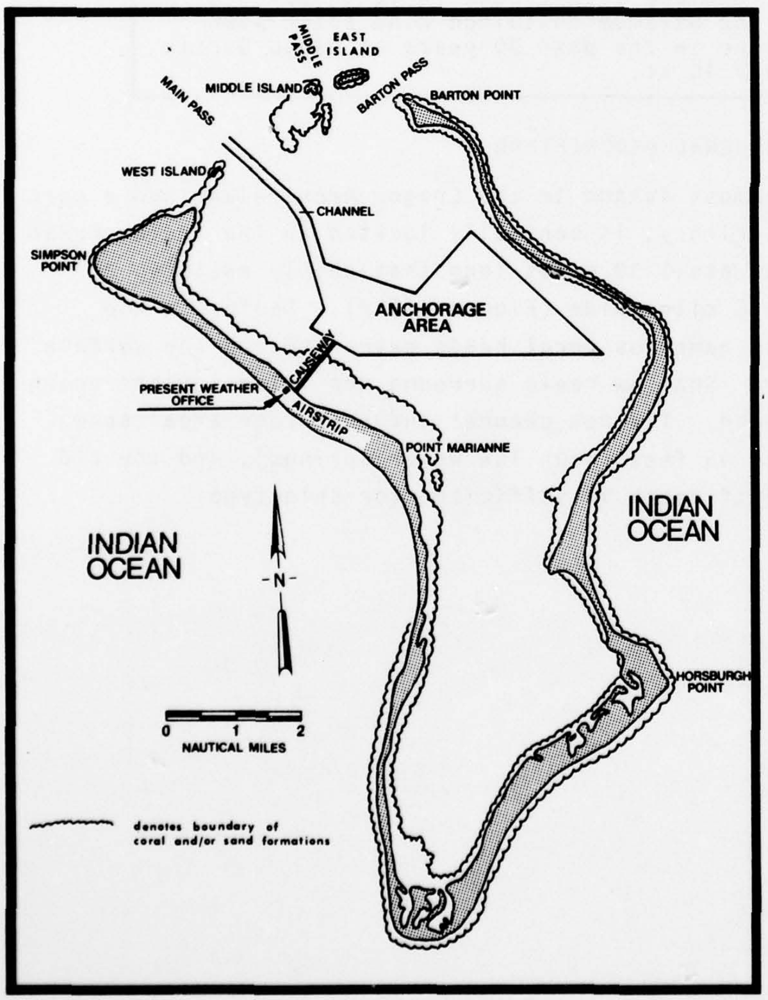

Figure XII-2. Diego Garcia.

2. TROPICAL CYCLONES AFFECTING DIEGO GARCIA

2.1 TROPICAL CYCLONE CLIMATOLOGY FOR DIEGO GARCIA

The majority of tropical cyclones that pose a threat to Diego Garcia (any tropical cyclone approaching within 180 n mi is considered a "threat") occur during the months of October through February, with a peak in January (Figure XII-3). Because Diego Garcia is located in the development area for southwest Indian Ocean tropical cyclones, many threat tropical cyclones form very close to the island. This can be seen in Figure XII-4, which shows formation points and track segments of tropical cyclones (1944-76) that passed within 180 n mi of Diego Garcia. The tropical cyclones generally head west-southwest and approximately 80% develop or pass to the south of the island.

Figure XII-5 shows the percentages of tropical cyclones that have passed within 180 n mi of Diego Garcia during the months of September through April. These percentages can be interpreted as probabilities of threat; for example, a tropical cyclone located at 9S, 81E has a 60% probability of passing within 180 n mi of Diego Garcia. A timetable for a storm's arrival could be estimated based on the typical speeds of movement for tropical cyclones in the Diego Garcia area of approximately 6-8 kt.

In the slightly more than 31 years of data examined, 33 tropical cyclones were found to have threatened Diego Garcia, or about one threat per year. In two of the years, however, four tropical cyclones threatened the island. It should also be noted that approximately 11 tropical storms and hurricanes occur annually in the southwest Indian Ocean. (Refer to Appendix I-C of Chapter I for the mean monthly and part monthly tropical storm and hurricane tracks for the southwest Indian Ocean.)

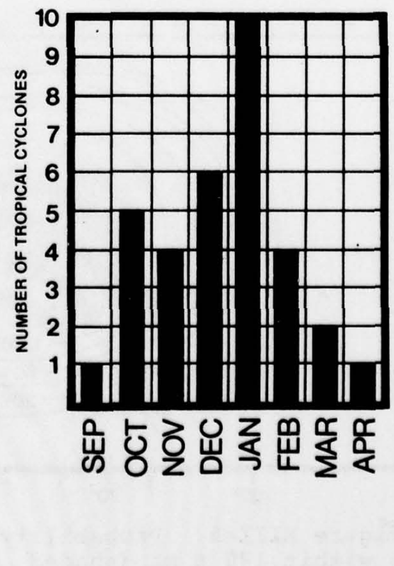

Figure XII-3. Monthly frequency distribution of tropical cyclones passing within approximately 180 n mi of Diego Garcia during the periods 1944-71 and Sep 1973-Dec 1976.

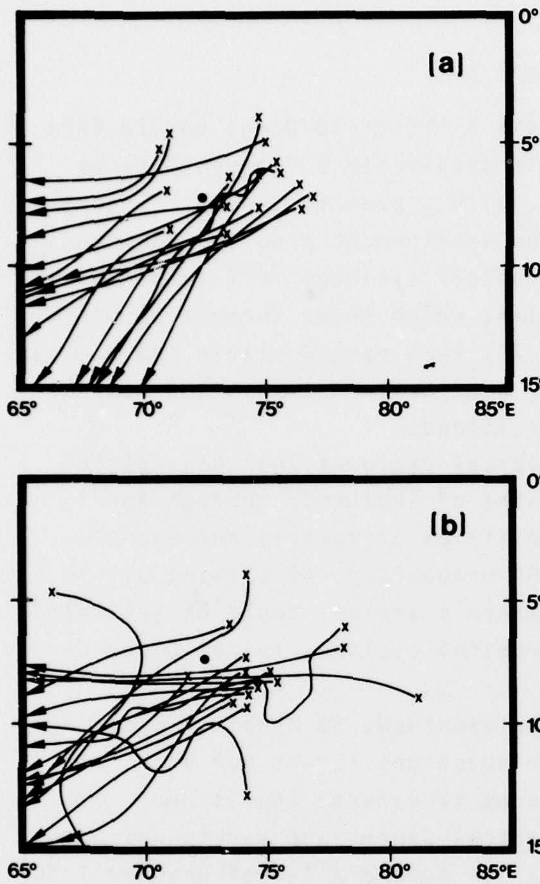

Figure XII-4. Track segments of 33 tropical cyclones that formed or passed within 180 n mi of Diego Garcia, with X showing point of formation:

(a) Track segments 1944-51 inclusive; none recorded during period 1939-43 incl.

(b) Track segments 1952-71 incl., plus Sep 73-May 76 incl.

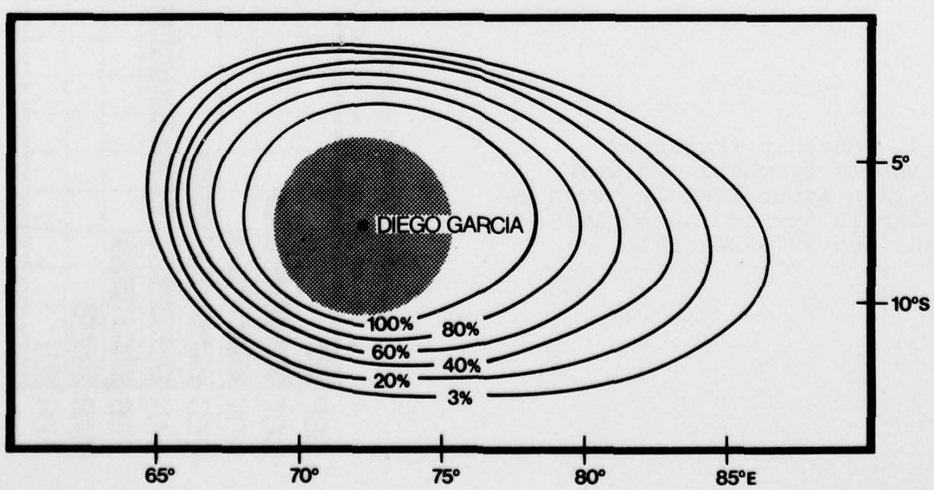

Figure XIII-5. Probability that a tropical cyclone will pass within 180 n mi (shaded circle) of Diego Garcia, based on data from Sep-Apr 1944-71 and Sep-Apr 1973-76.

2.2 TROPICAL CYCLONE ASSOCIATED WINDS AT DIEGO GARCIA

Because tropical cyclones tend to develop near Diego Garcia, close passages of intense and fully developed tropical cyclones are a rarity. This situation is enhanced by the fact that low latitude tropical cyclones are, in general, weaker than higher latitude tropical cyclones. In addition, low latitude tropical cyclones have been observed to have smaller wind distributions and to affect a smaller area, in comparison with higher latitude tropical cyclones of equal maximum intensity.

The maximum sustained wind at Diego Garcia attributed to a tropical cyclone during the last 30 years has been approximately 40 kt. This does not imply that winds of this strength or stronger will not affect the island in the future. Diego Garcia is in the development area for southwest Indian Ocean tropical cyclones and the potential for strong winds always exists, but the probability of their occurrence is extremely low.

Although tropical cyclones passing south of the island would probably affect the harbor more often because these storms are more intense the further they are away from the equator, the most dangerous situation would be a direct pass over the island or a close passage to the north that would contribute strong northerly winds during passage. Since 80% of the tropical cyclones in the last 31 years developed or passed to the south, northerly winds associated with a tropical cyclone would be extremely rare. If strong winds (60 kt) from the north did occur, seas in the anchorage area could reach up to 6-7 ft. Strong southerly winds (60 kt) could contribute 7-8 ft seas in the anchorage area. Because of the nature of the tropical cyclones in this region, the strong winds and rough seas would be of short duration.

3. THE DECISION TO EVADE OR REMAIN IN PORT

If winds of 35-40 kt are expected, ships should remain in the harbor. Due to the limited fetch of the lagoon, winds in this range would not generate excessive waves or swell. Small harbor craft could be moored at existing pier structures and larger ships could be anchored in the lee anchorage. Underwater reefs surrounding the harbor entrance also act to filter any exceptional sea or swell. If winds of about 60 kt or more are expected, ships should sortie from the lagoon because the low profile of the atoll does not offer any shelter to vessels in the lagoon when winds of this intensity are present. In addition, there are no mooring buoys in the anchorage area. A sortie north is therefore recommended for all severe tropical cyclone threat situations and it is reiterated that Diego Garcia is not a typhoon haven.